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In This Issue

Agricultural economists have an abiding interest in data. That interest arises from a need for the facts to test theories and a need to better understand agriculture's part of the economic world. In this issue's invited essay, Jim Bonnen argues the importance of understanding the nature of facts in research. He insists that the data side of empirical research has not had as much disciplined attention as theory. Failure to devote adequate attention to data in the course of inquiry results in bad habits in research. He lists six.

Because no single index can adequately reflect the effects of technology and structural change in agriculture's position in the economy, Fohlin, Robinson, and Schluter employ four indicators of the terms of trade. Two of the indicators are in terms of value added, one based on farm income and the other on GNP originating in the sector. The third is an output measure of agricultural prices received and deflated by nonagricultural GNP, and the fourth, similar to "parity," is a ratio of agricultural output prices to agricultural input and consumption prices. They show that disequilibria in the factor markets adjust slowly over time, and that capital is more responsive to terms of trade than labor. Productivity in agriculture grew more rapidly than in other sectors due to faster adoption of innovations. For this productivity, agriculture has been rewarded with declining value-added terms of trade and deteriorating relative prices for its output.

Bengston, too, addresses an indexing problem, research in State experiment stations. He examines research budgets to determine the real level of deterioration of nondefense investment in research. His alternative to the traditional GNP price deflator indicates a higher rate of inflation in experiment station research than the traditional measure. His second conclusion is that the U.S. Government, by using the GNP deflator, is understating the cost of research.

Knudson and Larson offer a framework for thinking about technical change. Their framework treats technical change as internal to an economy rather than as an external force. They show how the interrelationship of research, adoption, and regulation affects the direction of technical change, and they illustrate their concepts with the development of glyphosate-tolerant tomatoes.

The results reported in the book on elasticities in international agricultural trade, edited by Carter and Gardiner, are "quite discouraging," according to reviewer Blakeslee. He notes the wide variation in empirical results of research and the lack of modeling principles, even for narrowly defined problems. While it earns a read by those involved in agricultural trade modeling, Blakeslee feels that the collection will not be required reading 10 years from now.

Larson reviews Chambers' book on applied production analysis and finds treatment of the dual approach to the theory of the firm useful as a reference in applied research. He compliments the author's simple, straightforward style, and he is generally satisfied with the coverage of topics, even of technical change.

Anderson addresses the timeless topic of stability in agricultural markets. Her review of Sumner's book of readings on agricultural stability and farm programs is generally favorable. The essays in this small book perforce represent only partial coverage of the subject. She notes an absence of discussion of the connection between instability and uncertainty, volatility in other industries, and examples from a large number of specific markets.

To underscore the changing technology of information handling, Horsfield describes the data products now offered by USDA's Economic Research Service, and Reinsel summarizes the agency's policy on information dissemination. The importance of a well-informed exchange of data in research cannot be overemphasized. I urge you to read their brief notes.

Gene Wunderlich

On the Role of Data and Measurement in Agricultural Economics Research

James T. Bonnen

Agricultural economics was established as an empirical science. Its capacity, credibility, and resources are attributable to its capability as an empirical science and to its relevance to society's needs. This tradition and our reputation as agricultural economists are based on a balanced emphasis of (1) theory (including disciplines other than economics), (2) statistical and other quantitative measurement techniques, and (3) data. This is the three-legged stool that supports empirical tradition.

I believe that our profession has increasingly celebrated and rewarded theory and statistical methods while ignoring data (Bonnen, 1988).[1] Consequently, we are undermining our capacity as an empirical science and as a profession.

Claiming a body of inquiry to be a science depends on the grounds on which its knowledge is asserted. Empirical science depends on a theoretical statement of causation supported (or, more properly, not disproved) by empirical evidence. That evidence is formed around the same concepts as the theoretical explanation of causation. Data must be defined in the same terms as the theory being supported or negated. For the empirical test to be valid, the act of measurement must be logical, consistent, and appropriate to the measurement problem faced.

Agricultural economics appears to have devoted far too little attention to its data in relation to its theory and formal measurement processes. The ultimate basis of acceptance of a scientific theory is consensus, which occurs when theory is consistent, tests are valid, and empirical results are supportive. Consensus depends on the way a theory squares with a real world described by its data. The specification of that data requires the same underlying causal logic and rigor demanded of economic theory and statistical methods (Churchman).

Types of Research

Research serves multiple purposes and its products take many forms. For such purposes as research design, funding strategies, and data collection and management, it is convenient to distinguish three broad classes of research—disciplinary, subject matter, and problem solving.

Disciplinary research is the theory, empirical measurement, and the measurements techniques and methods used to explain a fundamental class of phenomena of concern in such disciplines as chemistry, microbiology, economics, or philosophy. Expanding such knowledge increases the capacity of a discipline to explain nature and human behavior. Data are necessary to any consensus about theories that make up a discipline.

Two other types of research are of an applied, multidisciplinary nature. Subject matter research combines different disciplinary products into knowledge useful to a set of decisionmakers who face a common set of problems. Agriculture is not a discipline but a subject matter, as are its subsets, such as animal science, agronomy, agricultural economics, and farm management. Practical decisions are often difficult to make based on general subject matter knowledge. A better informed decision depends on problem-solving research that further processes disciplinary and subject matter information into information more directly relevant to the specific problem on which a decision must be made. Problem-solving knowledge takes a form that is relevant to a single decisionmaker (or set of decisionmakers) who has a specific practical problem on which action is necessary. The processing of data and information produces a continuum in which distinctions differ in degree and purpose.

Problem-solving research differs from disciplinary and subject matter research in that it always seeks prescriptions, that is, "should" or "ought" statements that depend on values as well as on relatively value-free knowledge. Value data are frequently missing from agricultural economics research, and additional attention both to the content and form of value data would do much to enhance the quality of research and usefulness of the prescriptions. The acceptance of a production innovation, for example, may depend more on the values of producers or consumers, or on the rules that structure and govern the decision process, than on the technical qualities of the innovation.

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[1]See complete citation at end of article.

The Nature of Data, Information, and Knowledge

Data are symbolic representations of concepts, quantities, and actions and are the direct product of measurement or counting. Information is more. It usually combines data from different collection processes and subject matters always within some analytic interpretation. Interpretation may range from little more than formatting of data for presentation, to encoding in an index or scale, to modeling complex economic, engineering, and biological phenomena. Information is data that are processed, organized, interpreted, and communicated. The information's usefulness aids decisionmaking or subject matter evaluation, whether in science or in the practical world (Bonnen, 1977).

Finally, when one speaks of a body of (disciplinary or subject matter) knowledge, one is referring not just to tested (validated) information but tested information around which a scientific/professional community consensus has formed. Until a broad consensus of appropriate scientists accepts the validity of an information set, it is not generally treated as part of the corpus of knowledge in that discipline or subject matter.

Philosophies of Knowledge

Data, information, and knowledge, in a sense, form a continuum ranging from raw sense experiences to carefully catalogued wisdom.[2] A researcher's view of the role of data arises from that researcher's philosophy of knowledge. The positivists' concept argues that the only descriptive knowledge that can be objective and therefore scientific is value-free knowledge. Philosophers discredited extreme forms of positivism decades ago, rejecting the possibility of totally value-free knowledge. Physical scientists and most biological scientists have since cast off the limitations of logical positivism, but, paradoxically, it persists in the social sciences and still tends to dominate agricultural economics (Castle).

The premises of a positivistic philosophy of knowledge influence the data collected and its interpretation. Excessive positivism has not only resulted in a deficiency of value-oriented data, but it has narrowed the interpretation of available data. Observing the level of investment in soil conservation measures, for example, reveals only evidence of purchase and installation as relevant and objective measurements, not the farmer's attitudes, understanding, peer pressures, and goals.

Descriptive, positivistic knowledge is partially acquired through the five senses and is analytic (logical and conceptual) as well as synthetic (descriptive). It combines theory (statements of causation) with undefined primitive terms known through experience and interaction to produce contingent descriptive (empirical) statements about the perceived reality of nature and human and other behaviors (Johnson, pp. 41-53).

There are several other philosophic positions of consequence in social science research, including normativism and pragmatism. Clearly, one's philosophy of knowledge will dictate what is considered admissible as scientific evidence. A strictly positivistic approach will tend to exclude normative statements about what is good or bad, even if such statements are descriptive and, thus, factual.

Normative statements (about goodness and badness) can be regarded as empirical or descriptive statements. Thus, both positive and normative philosophic positions require data appropriate to their causal theories. Like value-free knowledge, value knowledge can be viewed as experiential, acquired through the five senses. Consequently, the same tests of truth used in positivism can be applied to knowledge of goodness and badness to support the claim of an objective, descriptive knowledge of values. These tests assess correspondence (experience), logical coherence (internal consistency), and clarity (the proposition to be tested is not ambiguous or vague and thus can be tested) (Johnson, pp. 41-64).

Both positive (relatively value-free) and normative (value) knowledge ultimately depend on a leap of faith that the five senses reflect something real in nature and are not perceptual illusions. Thus, both knowledges depend on philosophic "primitives," undefined terms known from experience (for example, good/bad, hot/cold). Neither value nor value-free knowledge may be regarded as knowable with certainty. All knowledge is contingent in science and thus subject to revision. A modern or balanced view would allow both positive and normative statements to be tested empirically for relations to theory.

Another view, that of the pragmatist, argues that value-free and value knowledge are interdependent in their consequences and that attempts to establish a clear distinction between them are arbitrary and mistaken. The truth of knowledge is viewed as dependent on its practical consequences. Thus, truth is instrumental and dependent on the use of knowledge. The ultimate test of truth is workability, although

[2]This section is an edited version of a similar discussion in (Bonnen, 1989). In both versions, a major intellectual debt is owed to Glenn L. Johnson, who has contributed greatly to my education and others' in the philosophy of science and philosophic value theory.

coherence and clarity are relevant *ex ante* tests of pragmatic prescriptions, the form in which most pragmatists frame any inquiry. This philosophic value position tends to be held by most experienced policymakers and, within the colleges of agriculture, by most extension staff and some problem-oriented teachers and researchers. Indeed, it is the typical philosophic value position of problem-solving (Johnson, pp. 65-75).

In my view, the philosophic ground on which one chooses to stand to address a particular inquiry should depend not only on the specific purpose of the inquiry, akin to pragmatism, but also on different philosophic positions which should be combined as appropriate to address various parts of complex inquiries (Johnson, pp. 22-7, 221-35). Many of the arguments among agricultural economists, even alleged disputes over empirical evidence, arise out of differences (often unconscious) in their philosophic views. We need to be more conscious of these differences and their advantages and disadvantages in different kinds of inquiries.

The Value of Research

The value of information from research is derived from its value in decisionmaking, whether in science or in practical problems. The value of information in a decision depends on the extent to which it is news to the decisionmaker. The value of new information is the value of the decision made with that information minus the value of the decision without it and minus the cost of the new information (Bonnen, 1977). Data collected as news has utility in decisions, with most of the utility going to the market participant who acts first.

Some Bad Habits

Research from an information system point of view acknowledges complexity and seeks balanced attention to all elements of inquiry. Failure to acknowledge the interdependence of all the elements of inquiry can result in some bad habits, which can be destructive of effective research and professional performance. These bad habits include:

An exclusive or excessive emphasis on one of the three legs of the empirical tradition in science to the exclusion or detriment of the others. The most common is an excessive focus on theory development without an adequate empirical test of the theory. Some use no data at all. They just publish mathematical proofs of the logical consistency of the theory. Others use inappropriate secondary data formed for a different purpose around concepts that differ significantly from those to be tested. Sophisticated econometric technique is then used in an attempt to compensate for the weaknesses (Leontief).

The growing lack of experience with primary data collection in agricultural economics. The rising economic value of time and the labor-intensive nature of data collection are part of the reason for the lack of experience. But often the only accurate way to test a concept is with data collected specifically for the purpose.[3] The profession is slowly losing touch with the problems involved in the designing and processing of data, which in turn are critical elements needed in selecting and modifying appropriate data for modeling.

Lack of extensive hands-on experience with agricultural subject matters. This was not a problem in earlier times. Most agricultural economists then grew up in rural communities or on farms and brought some substantial command of agronomy, animal science, and other relevant fields and disciplines to graduate training in agricultural economics. This is no longer the case. Few modern agricultural economists see any need to learn much about complex multidisciplinary subjects before modeling or doing other types of research on them. One cannot use the research of other disciplines or collaborate effectively with scientists in other fields without adequate understanding of the relevant fields and disciplines. The capacity to judge accurately the correspondence between concepts and reality is not what it used to be in agricultural economics. This, however, is offset somewhat by greater knowledge in other areas, but there is a limit to the substitution possibilities.

Failure to do sufficient preliminary data analysis in preparing for modeling, forecasting, and other analytic processing of data. That is, economists do not work directly with the microdata sets sufficiently to learn the strengths and weaknesses of the data they are preparing to use. Rather, they plunge ahead, working with various (usually secondary data) aggregates that often obscure many of the weaknesses and characteristics of the data.

Excessively narrow and inflexible philosophic commitment (to logical positivism, for example, or a narrow normativism). This limits one's view of the world and choice of data and methods in research. Failure to let research purpose guide epistemological choices can constrain and distort the quality of one's research as well as one's judgment of other research.

[3]See (Bonnen, 1988) for a discussion of possible reasons for this decline in primary data collection.

The common but arrogant belief that the only legitimate, respectable, or useful research role for agricultural economics is disciplinary research. All else (subject matter and problem-solving research) is second-rate science—a view common to the elitism of some basic scientists. This attitude has produced an equally erroneous reaction in some agricultural economists who will tell you that the only legitimate role is limited to subject matter and problem-solving research. Both views destroy the balance of commitment needed for effective performance in agricultural economics research. This lack of balance is not limited to agricultural economics and is undermining the capacity of and commitment to the land grant idea in many colleges of agriculture. The large number of institutions in trouble with their legislature and clientele attest to this and other difficulties.

The output of agricultural economics that generated our resources and societal support included disciplinary, subject matter, and problem-solving information. We now tend to focus so much on the discipline of economics that the profession's incentives and capacity for producing subject matter and problem-solving information is slowly eroding. With this comes an erosion of relevance to society's needs and eventually the support of research. The profession needs the multidisciplinary capability to produce subject matter and problem-solving knowledge.

References

1. Bonnen, James T. "Improving the Socioeconomic Data Base," *Agriculture and Rural Areas Approaching the 21st Century: Challenges for Agricultural Economics*. eds. James Hildreth, Katherine Lipton, Ken Clayton, and Carl O'Conner. Ames: Iowa State University Press, 1988, pp. 452-83.

2. ____________. "Assessment of the Current Agricultural Data Base: An Information System Approach," *A Survey of Agricultural Economics Literature*. Vol. 2, eds. Lee R. Martin and George G. Judge, and others. Minneapolis: University of Minnesota Press, 1977, pp. 386-407.

3. ____________. "Role of the Social Sciences in the Policy Arena: Implications for Agricultural Economics," *Southern Journal of Agricultural Economics*. Vol. 21, 1989.

4. Castle, Emery N. "Economic Theory in Agricultural Economics Research," *Journal of Agricultural Economics Research*. Vol. 41, No. 3, U.S. Dept. Agr., Econ. Res. Serv., Summer 1989.

5. Churchman, Wes. *The Design of Inquiring Systems*. New York: Basic Books. 1971.

6. Johnson, Glenn L. *Research Methodology for Economists*. New York: Macmillan Co. 1986.

7. Leontief, Wassily W. "Theoretical Assumptions and Non-Observed Facts," *American Economics Review*. Vol. 75, 1971, pp. 293-307.

Terms of Trade and Factor Commitments in Agriculture

Caroline Fohlin, Sherman Robinson, and
Gerald Schluter

Abstract. *U.S. agricultural economic growth in this century has been characterized by a slow rise in the demand for food and faster growth in farm output as against nonfarm productivity. In such an environment, one expects the size of the farm sector to decline as a share of the rest of the economy. What is not so clear is the effectiveness of the price system in signaling the appropriate resource adjustments or of the resource market in responding to available signals. We examine four terms-of-trade measures conceptually and, since 1929, empirically. We find that even distortions from farm programs have not offset the long-term trend of declining terms of trade. Labor and capital markets respond, albeit imperfectly and slowly.*

Keywords. *Agricultural terms of trade, agriculture, economic growth.*

Since the 1930's, Federal farm programs have sought to help farmers adjust to changing market forces. These programs, however, have ramifications outside the agricultural sector. They affect not only farm incomes but market prices, producer incentives, and the allocation of resources across sectors.

Agricultural economics has long used relative prices to measure the impact of agricultural programs. For example, parity prices have frequently been used to indicate farmer well-being relative to others in the economy. This notion has been criticized because, as a measure of well-being, it inadequately accounts for technological and structural changes in the economy. This paper presents a variety of relative prices or terms-of-trade indicators, each of which captures a specific market mechanism or income effect. Together, these indicators form a composite of the agricultural economy relative to other sectoral economies.

We define four indicators of the agricultural terms of trade. In contrast to the single "parity prices" index, two indicators separately measure "resource pull" effects, a third measures relative real incomes (or well-being), and a fourth measures relative prices from the point of view of demanders. We show the historical paths of these measures since 1929 and describe how various domestic and international shocks affected them. We discuss how the indices reflect long-term changes in the agricultural economy and how the observed movements in the different terms-of-trade measures are linked to changes in the relative position of agriculture in the economy, including resource movements and relative productivity growth among sectors.

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Value-Added Terms of Trade

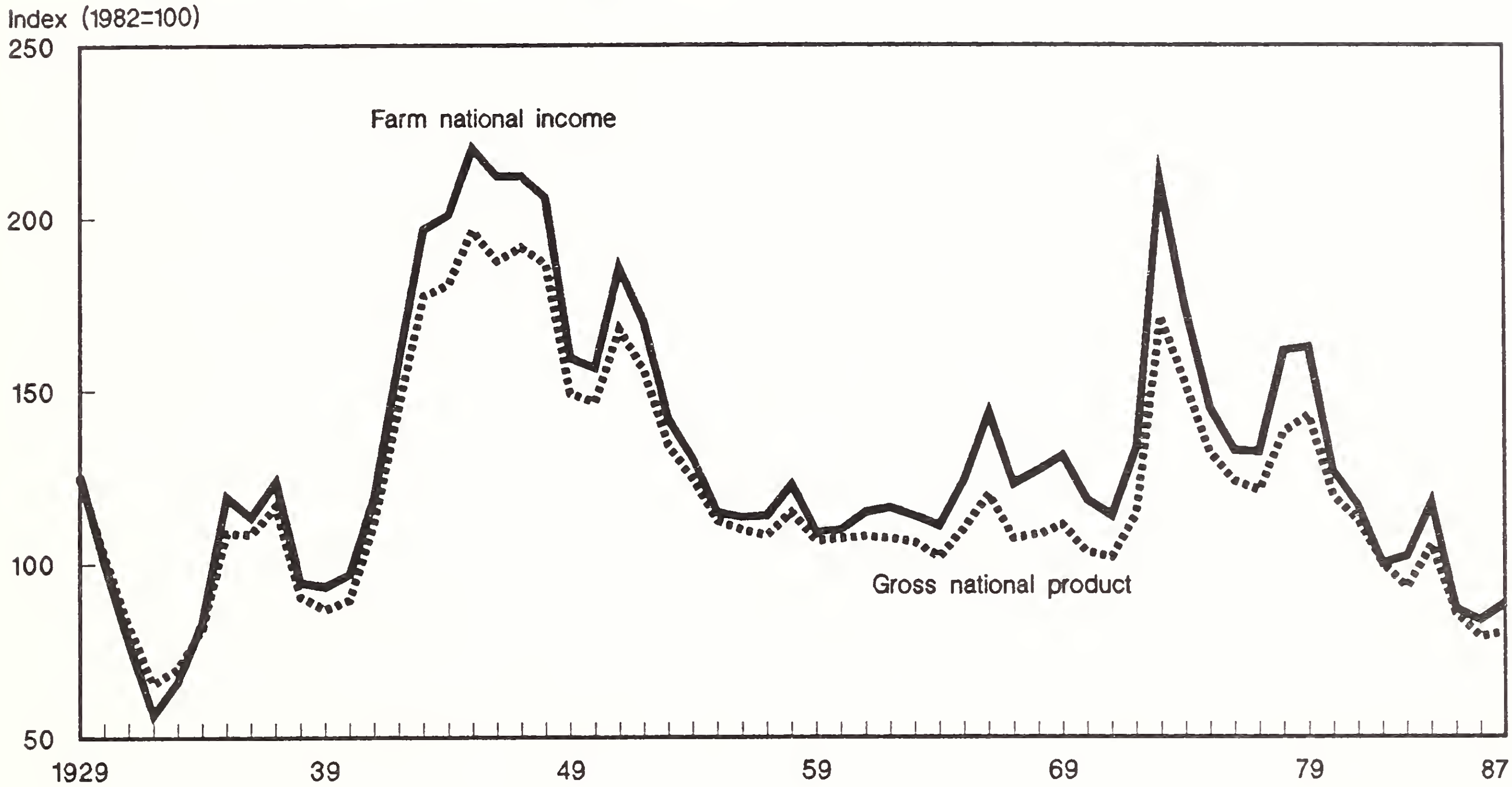
To calculate the value-added terms of trade, the ratio of the agricultural gross national product (GNP) deflator to the nonagricultural GNP deflator, we used data from (*8*, *9*).[1] This ratio measures factor income per unit of real value added in agriculture relative to that in the nonagricultural sectors. A unit of real value added is a composite indicator of primary factor inputs—capital, labor, and land. If all factors are mobile and factor markets function perfectly, then each primary factor would earn the same return in all sectors. The value-added terms of trade would then be constant, on average, over time. We did not, however, observe such constancy. Land is a sector-specific primary factor, so one would expect to find some variation in the value-added terms of trade with changes in land values over time. Except for land, changes in the value-added terms of trade indicate continuing disequilibrium in the factor markets and denote resource-pull effects that should lead to further factor reallocation.

We define two versions of the value-added terms of trade, one using farm national income and one using sectoral real value added, or GNP originating in the sector. The GNP version includes the effects of price supports on the terms of trade. The farm national income version incorporates the impact of transfer payments as well.[2] Figure 1 plots the two variants over time. The two measures of the value-added terms of trade generally move together, with the national income version above the GNP version in all years. They dropped sharply during 1929-32, increased during 1932-37 to near-1929 levels, then declined

[1] Italicized numbers in parentheses cite sources listed in the References section at the end of this article.

[2] In computing the national income version, we use the U.S. Department of Commerce's Bureau of Economic Analysis (BEA) estimates of the real value of subsidies. As an alternative, we explored using the GNP deflator to deflate nominal subsidies. The resulting national income value-added terms of trade series is similar, with some significant differences in the 1959-72 period, when the BEA figures showed improvement, while the series computed with the GNP deflator showed a flat trend.

Figure 1
Two versions of the value-added terms of trade



until 1939. These movements mirrored the macroeconomic cycles of the Great Depression: the initial crash in 1929 accompanied by a sharp decline in relative agricultural prices, a strong recovery to 1937, and another major decline until the advent of the war economy.

World War II triggered a sharp upturn in the agricultural economy. Both measures of the value-added terms of trade peaked in 1945 and remained high through 1948. The postwar economic readjustment led to downward trends from 1948 to 1955, with a short, sharp improvement in 1951-52 due to the Korean War. The GNP value-added terms of trade remained nearly constant during the period of relative economic stability between 1955 and 1972, while the farm national income version improved slightly. Although there were some small variations in the GNP value-added terms of trade during this period, there were no large fluctuations until 1971 when the Smithsonian Agreement between major Western nations realigned their currencies and resulted in a devaluation of the dollar.

The 1970's were characterized by major swings in the macroeconomy and in the value-added terms of trade. The measures increased to above Korean War levels in 1973, but the trend has been strongly negative since 1974. In 1986, the GNP value-added terms-of-trade measure fell to its lowest point since 1934.

The post-Korean War movement of the national income value-added terms of trade meant that farm programs were successful in enhancing real incomes in agriculture. The national income value-added terms of trade increased on average between 1955 and 1972, while the GNP value-added terms of trade declined slightly. With the 1973 ascent, the national income value-added terms of trade reached World War II levels. When the GNP value-added terms of trade hit a 52-year low in 1986, the national income value-added terms of trade did not follow. However, the national income version also shows more volatility than does the GNP version. Throughout the 1970's and 1980's, when the GNP value-added terms of trade increased, the national income value-added terms of trade rose even more strongly. And, when the GNP terms of trade declined, the national income terms of trade dropped at least as much.

Comparing the two versions of the value-added terms of trade provides some insights into the effects of farm programs on the agricultural sector's ability to attract and hold a share of society's resources. The national income version of the value-added terms of trade differs from the GNP version by the dropping of taxes embodied in market prices (indirect business taxes)

and depreciation allowances and by adding Government transfer payments. Farm programs apparently influence the national income measure more than the GNP version. Most farm programs primarily affect market prices, however, and both measures use the same output and purchased input measures. The disparate influences of farm programs on these measures result directly from the effects of government transfer payments and indirectly from effects farm programs may have on indirect business taxes and on depreciation through the values of assets, both working and fixed. While transfer payments have successfully supplemented income levels for agricultural labor, land, capital, and management, they have not stabilized agricultural income over time. Income transfer programs have cushioned the drops, but they have padded the rises and have provided little consistent hindrance of wide price swings.

Internal and Output Terms of Trade

To calculate the internal terms-of-trade index, the ratio of an index of the prices received for agricultural output to a combined index of the prices paid for agricultural inputs and of consumption by farm households, we used data from (*7*). This index is an indicator of the purchasing power of agricultural goods in terms of commodities bought by farmers. Of the indices we consider, this is the closest to the traditional definition of "parity" prices.[3]

The output terms of trade is the ratio of the agricultural prices received index (*7*) to the nonagricultural GNP deflator (*8*, *9*) and indicates the purchasing power of agricultural goods in terms of all nonagricultural domestically produced goods. The ratio differs from the internal terms of trade only in the definition of the denominator. Figure 2 shows the output and internal terms-of-trade indexes over time. The movements in the output terms of trade closely paralleled those of the internal terms of trade, though the index dropped at a less dramatic rate from 1973 to 1987. Both indices reached a low in 1986. The swings in the output terms of trade generally have been more dramatic than those in the internal terms of trade, probably because the internal terms-of-trade index includes more of the same commodities in both numerator and denominator. The similarity in turning points, however, indicates that both measures have responded to the same economic shocks.

The output and internal terms of trade have followed a trend similar to that of the value-added terms of trade (fig. 1), with some notable differences. During the Great Depression, the output and internal terms-of-trade indexes dropped at the same rate as the value-added terms of trade. However, the internal terms-of-trade measure surpassed its pre-Depression high during the recovery of the mid-1930's. The output and internal terms of trade rose together during the World War II boom and fell only slightly before climbing again during the Korean War.

After the post-Korean War readjustment, the output and internal terms-of-trade indexes continued to decline, but the two value-added indexes leveled off. The long-term decline in the output and internal terms of trade has continued since 1951, with a major but temporary upswing in 1973. During the Kennedy round of the GATT negotiations of the early 1960's, the European Economic Community refused to discuss issues affecting agriculture (*3*). The result was an agreement that favored an increase in world industrial trade at the expense of agriculture. In addition, with the overvalued dollar of the 1960's, U.S. agricultural exports were relatively expensive to the rest of the world.

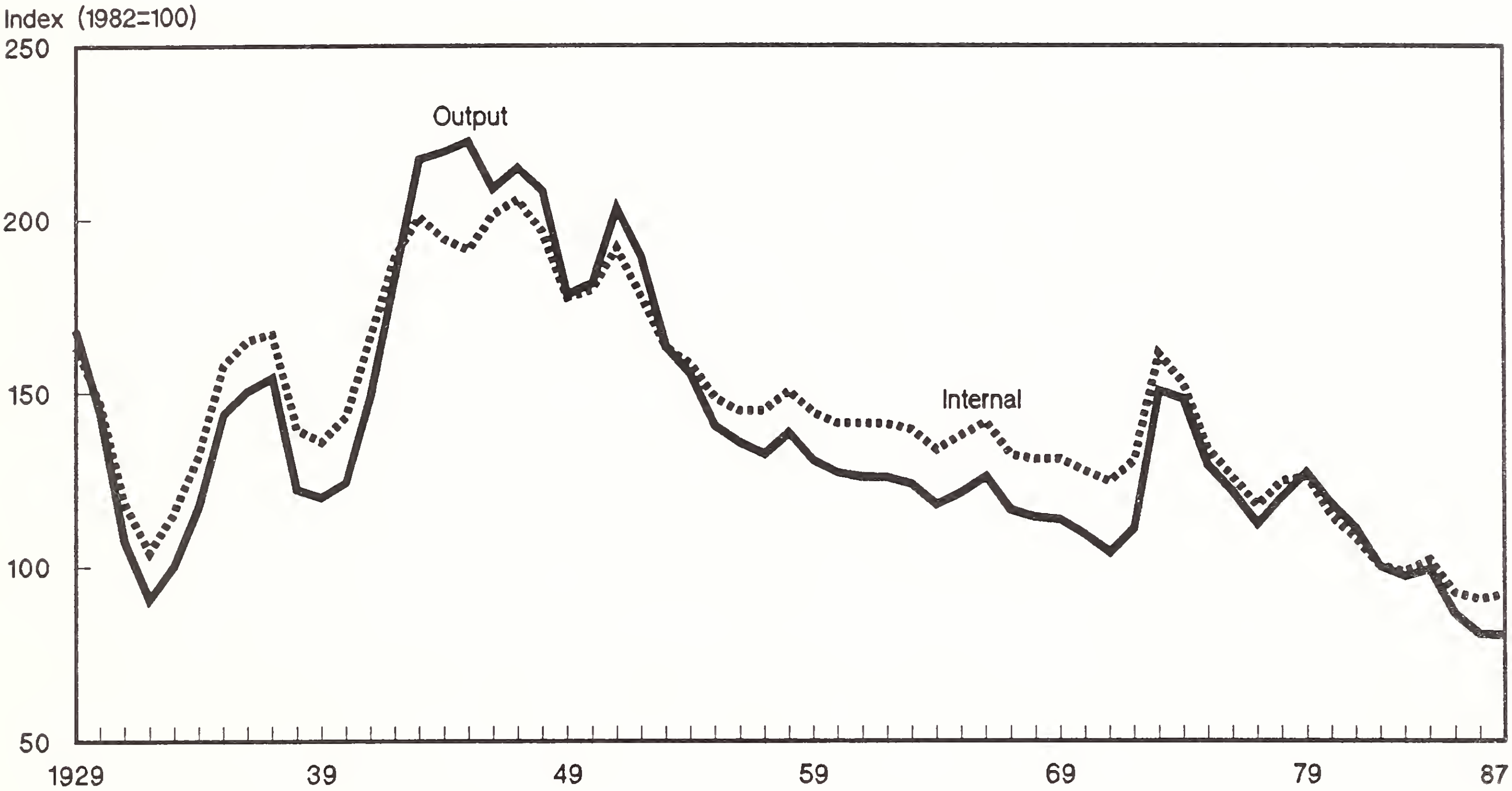
Agricultural prices peaked relative to other commodity prices in 1973, then dropped. The Smithsonian Agreement of 1971 specified an 8.57-percent devaluation of the U.S. dollar, thereby lowering the relative price of U.S. agricultural exports to the rest of the world. In 1973, the Smithsonian Agreement collapsed and the dollar floated down. Soon thereafter, developed countries, including Japan and some European nations, increased their purchases of the now cheaper American agricultural exports. Additionally, the Soviet Union agreed to a major grain purchase from the United States to support increased meat production. However, the formation of OPEC and the subsequent oil price shock in 1973-74 caused nonagricultural prices to jump.

The increase in worldwide demand in the mid-to-late 1970's, accompanied by a slower increase in supplies than was expected, caused agricultural prices to soar. Nonagricultural prices were also increasing, however, so the effect was only a slight increase in the output and internal terms of trade in 1978-79.

A second oil price rise in 1979 caused another sharp increase in commodity prices. In October of that year, the Federal Reserve tightened the money supply, causing higher interest rates and lower domestic aggregate demand. This action increased the value of the dollar, making American exports relatively more expensive to the rest of the world. There was continuing appreciation of the dollar through 1985. The January 1980 grain embargo on sales to the Soviets contributed to large surpluses and a subsequent price decline in agriculture. The output and internal terms

[3]This definition of parity is not quite equivalent to the legal definition of price parity. If we had used the 1910-14=100 indices, the internal terms-of-trade ratio would be the parity ratio. Teigen (*6*) discusses the evolution of the definition.

Figure 2
Internal and output terms of trade



of trade dropped below the mid-Depression level in 1982 and hit their all-time low in 1986.

Analysis

Trends in each of the above terms-of-trade indexes suggest how the economic climate affected agriculture and how factors were committed in the sector.

Table 1 gives the average yearly growth of each price index from 1955 to 1972 and from 1973 to 1987.[4] The average yearly increase of the agricultural GNP deflator dropped from 3.7 percent in the first period to 1 percent in the second period, and that of the index of prices received for agriculture only increased from an average of 1.4 percent per year to an average of 2.3 percent per year. Meanwhile, the average yearly increases in the prices paid index and the nonagricultural GNP deflator jumped from 2.3 percent and 2.9 percent, respectively, in the first period, to 6.4 percent and 6.7 percent in the second period.

Table 1 shows the long-term deterioration in all indexes of the agricultural terms of trade, with acceleration in the rate after 1973. Near stagnation in agricultural prices and strong growth in nonagricultural prices combined to lead to this long-term deterioration. These trends have continued.

The value-added terms of trade is an indicator of relative real factor incomes. Declining relative factor income should signal factors, such as labor and capital, to move to other sectors. The two versions of the index, however, embody different assumptions about incentives. If income transfers do not affect producer incentives, then the GNP version better measures resource-pull effects. To the extent that farmers respond to income differentials, including transfers, then the national income version is more appropriate.

If all factors of production were perfectly mobile, one would expect each factor to receive the same rate of

Table 1—Average annual growth rates of price indexes

Index	Period 1, 1955-72	Period 2, 1973-87
	Percent	
Agricultural GNP deflator	3.67	0.97
Prices received index	1.41	2.33
Nonagricultural GNP deflator	2.94	6.72
Prices paid index	2.33	6.40

[4]The growth rates were estimated from log linear regressions of the variables against time for each subperiod.

remuneration in all sectors, and hence, little change in the value-added terms of trade over time.[5] Labor and capital, however, are not perfectly mobile. Changes in the terms of trade lead to disequilibria in the factor markets with only slow adjustment over time.

Figure 3 reproduces the farm national income version of the value-added terms of trade, along with the percentage of the work force employed in agriculture and the percentage of the real capital stock committed to agriculture from 1947 to 1987. The structure of employment did not follow the movements in the terms of trade. During the period of nearly constant value-added terms of trade (1955-72), the portion of the work force employed in agriculture dropped at an average yearly rate of 4.77 percent. However, during 1973-87, when the value-added terms of trade were declining rapidly, albeit from historically high levels, agriculture's share of employment fell at an average rate of only 2.58 percent per year. This trend seems to contradict the conventional wisdom that labor, the more mobile factor, should respond to the declining value-added terms of trade by leaving the sector. Clearly, workers lack the incentive, tangible or otherwise, to move out of agriculture as fast as the deterioration in the terms of trade would indicate. The addition of direct Government payments to agriculture, by increasing the value-added terms of trade, may have obscured the market forces that were present.

Although labor did not adjust fully to the changing terms of trade, capital stocks fluctuated as expected. From 1955 to 1972, agriculture's share of capital stocks remained fairly steady, dropping only 1.67 percent per year on average. Agriculture's share reacted slightly to the dramatic 1973 peak in the agricultural terms of trade, then began an accelerated decline during the post-1973 slide. The fact that agriculture's share of the capital stock fell faster than its share of employment could reflect the fact that part of the unexpectedly large drop (according to the terms-of-trade indexes) in agriculture's share of employment during 1955-72 came from a substitution of capital for labor. Thus, farm labor adjustment may have been more sensitive to relative agricultural labor and capital costs, while capital costs and agricultural capital allocation were more sensitive to the agricultural/nonagricultural terms of trade.

Though the output terms of trade are more volatile than the internal terms of trade, increasing faster in times of relative improvement and decreasing more sharply in times of relative decline, both support the conclusions about labor and capital commitments in agriculture.

Agriculture's terms of trade are expected to decline as an economy develops (*1*). The income elasticity of demand for agricultural products tends to be low, causing prices to fall if agricultural production grows faster than population. Meanwhile, higher incomes increase demand for nonagricultural goods, pushing up prices in those sectors. While automation in agriculture increased supply, demand did not keep pace, causing more downward pressure on farm prices. And because the decline in employment has been slower during the past 15 years, and capital stocks have only recently begun to decrease significantly, overproduction has persisted. Considering these effects with the historical factors described above, prices paid by farmers unsurprisingly grew twice as fast as prices received by them between 1955 and 1972 and almost three times as fast from 1973 to 1987.

The combination of declining relative prices and a constant value-added terms of trade that existed between 1955 and 1972 indicates that total factor productivity grew faster in agriculture than in other sectors. The farm sector adapted faster to innovations, thereby allowing for higher levels of production. At the same time, movements in the farm national income version of the value-added terms of trade during this period seem to indicate that the average yearly drop in employment of 4 percent was excessive.

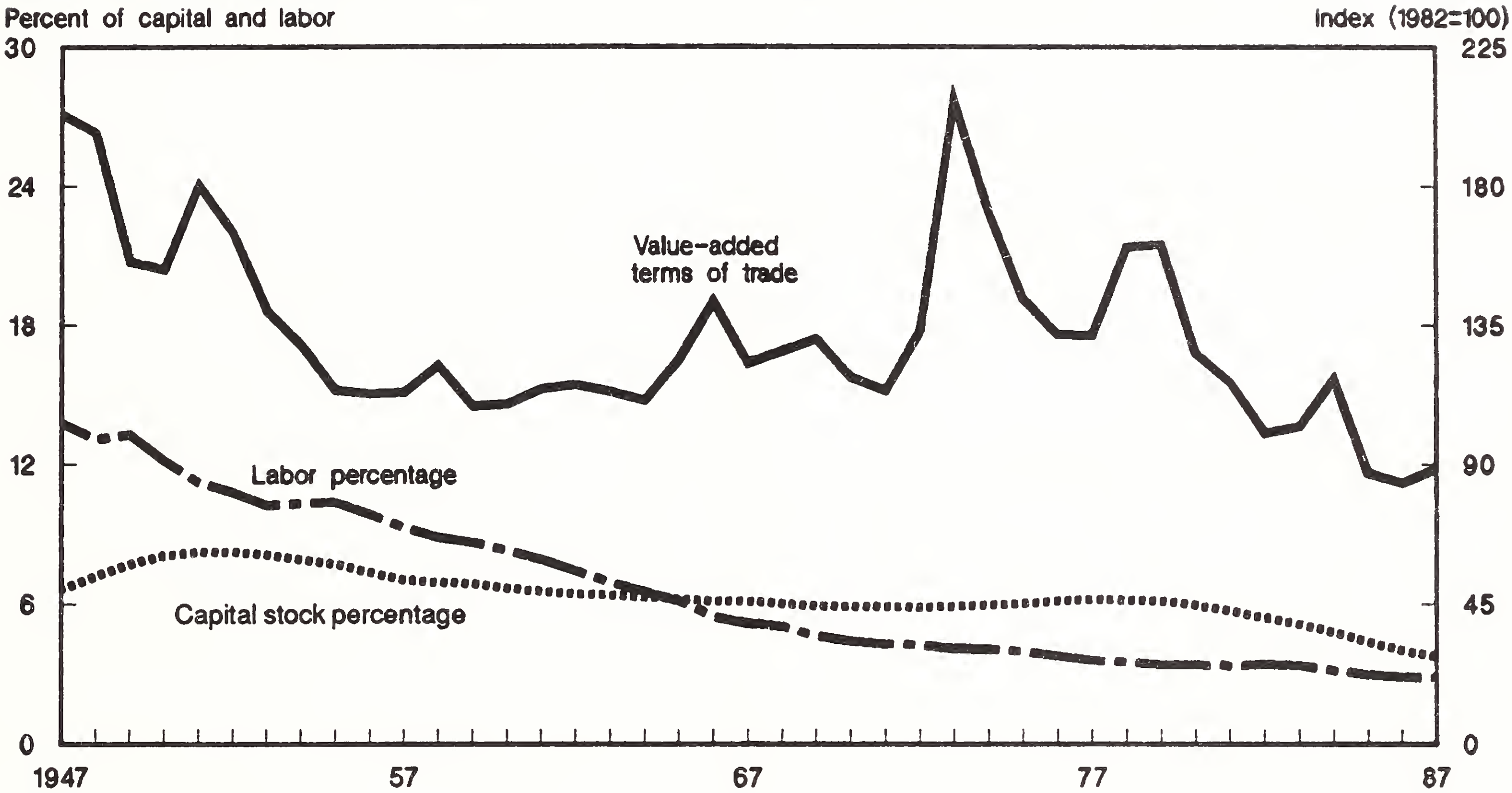
The value-added terms of trade, however, during the past 15 years, has been declining with the internal and output terms of trade. This combined movement indicates that the market is signaling additional factors to leave the sector, assuming productivity is constant. Even when we consider the direct payments by the Government in the value-added terms of trade, the implication is the same: sector value added has been deteriorating along with the relative prices for agricultural products, signaling factors to move to other sectors.

Conclusions

The agricultural economy in the United States has suffered recently, and agricultural policy has attempted to slow that decline. But, one unstated goal of the policy, to allow farmers to shrink the sector on their own, has not been met. Price supports, which are intended to keep prices between average variable costs and average total costs, are not stemming the deterioration in relative prices in agriculture. The direct Government payments, which constitute much of the program, are either sending the wrong signals

[5]This result also assumes that the indices correctly account for changes in factor quality, technology, and firms' institutional environment.

Figure 3
Labor and capital shares in agriculture and value-added terms of trade



or are obscuring the natural market forces that would tend to reallocate factors to other sectors.

References

1. Anderson, Kym. "On Why Agriculture Declines with Economic Growth," *Agricultural Economics*. Vol. 1, 1987, pp. 195-202.

2. Fohlin, Caroline, Sherman Robinson, and Gerald Schluter. "Value Added Terms of Trade and Sectoral Factor Commitments." Paper presented at the Fifteenth Annual Convention of the Eastern Economic Association, Baltimore, March 3-5, 1989.

3. Porter, Jane M., and Douglas Bowers. "A Short History of U.S. Agricultural Trade Negotiations." ERS Staff Report AGES 89-23. U.S. Dept. Agr., Econ. Res. Serv. Aug. 1989.

4. Schluter, Gerald. "Factor Income in Farming and the General Economy," *Research in Domestic and International Agribusiness Management*. Vol. 71, 1987, pp. 109-22.

5. Schluter, Gerald, and Gene K. Lee. "Effects of Relative Price Changes on U.S. Food Sectors, 1967-1978," *Agricultural Economics Research*. Vol. 33, No. 1, Jan. 1981, pp. 1-12.

6. Teigen, Lloyd D. *Agricultural Parity: Historical Review and Alternative Calculations*. AER-571. U.S. Dept. Agr., Econ. Res. Serv. June 1987.

7. U.S. Department of Agriculture, National Agricultural Statistics Service. *Agricultural Prices*. Selected annual summaries.

8. U.S. Department of Commerce, Bureau of Economic Analysis. *The National Income and Product Accounts of the U.S., 1929-82*. Sept. 1986.

9. U.S. Department of Commerce, Bureau of Economic Analysis. *Survey of Current Business*. Selected issues, 1983-88.

A Price Index for Deflating State Agricultural Experiment Station Research Expenditures

David N. Bengston

Abstract. *The extent to which inflation has eroded the real purchasing power of public agricultural research budgets is poorly understood. Official Government research and development (R&D) statistics use the gross national product (GNP) deflator to express research expenditures in constant dollars, despite the serious shortcomings of such a broad indicator of inflation for deflating research expenditures. A State Agricultural Experiment Station (SAES) research price index is calculated in this paper and compared with the GNP deflator. The GNP deflator substantially underestimated the rate of inflation in SAES research in recent years mainly due to real growth in faculty compensation during the 1980's. The divergence between the SAES research price index calculated in this study and the GNP deflator indicates that the purchasing power of SAES research is significantly less than estimates based on the GNP deflator would suggest.*

Keywords. *Price index, Laspeyres, State Agricultural Experiment Stations, research, GNP deflator.*

Nondefense research budgets have stagnated or declined in many sectors of the U.S. economy during the 1980's, increasing concern among those who feel this will hamper productivity growth and international competitiveness. Although the decline has been substantial for many types of research, little is known about the extent to which inflation has further eroded the real purchasing power of research budgets. No widely accepted and fully satisfactory price index exists for measuring the impact of inflation on research. Government R&D statistics use the implicit price deflator for gross national product (GNP deflator) to express research expenditures in constant dollars, despite the serious shortcomings of such a broad measure of inflation for a highly specialized activity like research. The GNP deflator has tended to underestimate the rate of inflation in industrial and academic research expenditures in recent years (*8, 12, 20*).[1] Reports by the General Accounting Office (*28*) and the Office of Technology Assessment (*22*) have recommended the use of alternative price indexes for research.

Several agricultural research price indexes (RPI's) have been constructed. Some have been based on personnel expenditures or average salaries for one type of personnel, for example, associate professors (*4, 5*). The most serious shortcoming of personnel-based RPI's is that they assume that changes in the relative prices of nonpersonnel research inputs have been identical to the trend in prices for personnel inputs (or a subcategory of personnel). This assumption may introduce some bias because others have found that prices for personnel and nonpersonnel research inputs have increased at different rates and that subcategories of research personnel have increased in price at different rates (*12, 15, 17*).

Murphy and Kaldor (*15*) developed a Laspeyres RPI for the State Agricultural Experiment Stations (SAES) for fiscal years (FY) 1973/74 to 1978/79. Survey data on personnel and nonpersonnel direct research expenditures were obtained from 25 SAES. Five categories of nonpersonnel (scientific, professional, technical, clerical, and administrative) and five categories of nonpersonnel research expenditures (travel, supplies, equipment, utilities, and other) were included in this index. Proxy price indexes were used to represent the price trend in each of the nonpersonnel input categories. Murphy and Kaldor's index increased an average of 6.2 percent per year between 1973/74 and 1978/79 compared with 7.9 percent for the GNP deflator (July-June FY basis). The lower average rate of inflation in agricultural research came mainly from scientists' compensation, a major component of research costs, which rose an average of 5.9 percent per year during this period. Eddleman (*7*) updated Murphy and Kaldor's index through FY 1979/80.

Pardey and others (*19*) developed two current weighted Paasche indexes for SAES research. The first index covered FY 1889/90 to FY 1984/85 and was based on three research input categories (land and buildings, plant and equipment, and research labor plus recurrent operating expenses). The second Paasche index covered FY 1930/31 to FY 1984/85 and included four input categories (labor and operating expenses were separated). Both indexes used proxy price indexes for all input categories. Comparison of these indexes to the GNP deflator in recent decades reveals that the GNP deflator tended to overstate the rate of inflation in SAES research during the 1970's relative to Pardey's index. During the first half of the 1980's, the average annual rate of inflation was underestimated by the GNP deflator.

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[1]Italicized numbers in parentheses cite sources listed in the References section at the end of this article.

Huffman and Evenson (*9*) constructed a Laspeyres price index for U.S. public (USDA and SAES) agricultural research for 1888 to 1985. They used an index of average salaries paid to college and university faculty members as a proxy for all personnel expenditures, and the wholesale price index deflator served as a proxy for nonpersonnel expenditures. The estimated average annual rate of inflation based on this index was slightly less than the GNP deflator during both the 1970's and the first half of the 1980's.

All the agricultural RPI's discussed above, except Murphy and Kaldor's, suffer from the same shortcoming: scientists' compensation, perhaps the most critical component of research expenditures, was represented by various proxies, such as average salaries for all college and university teachers. Price indexes based entirely on proxies are valuable if those proxies are reasonably accurate. But, a variety of factors may reduce the accuracy of the proxies that have been used for SAES faculty salaries. Recent faculty salary surveys have revealed much variability in average salaries in different academic fields (*1, 17*). Average faculty salaries in fields like engineering and business have been inflated by bidding wars that have boosted salaries for junior faculty. Weak job markets in other fields have depressed average salary levels. Faculty salaries at institutions with collective bargaining contracts have averaged 13 percent higher than salaries at institutions without collective bargaining (*14*).

The purpose of this paper is to construct an agricultural RPI using salary data for the SAES and appropriate proxy price indexes. The model and data are described in the next section, followed by a comparison of the calculated agricultural RPI to the GNP deflator. Implications for agricultural research policy are discussed in a concluding section.

Model and Data

A Laspeyres formula was used to construct an agricultural research price index (AG-RPI). I selected the Laspeyres formula because it is widely used and is better understood by users than the Divisia formula. The Paasche formula could not be used because expenditure weights were not available on an annual basis. The calculated index consists of four main components or subindexes. Each subindex is weighted by its relative share of total expenditures to produce the aggregate index:

$$\text{AG-RPI} = w_f I_f + w_a I_a + w_o I_o + w_n I_n, \tag{1}$$

where w_f, w_a, w_o, and w_n are expenditure weights for faculty compensation, research administrator compensation, other personnel compensation, and nonpersonnel direct research expenditures, respectively, and I_f, I_a, I_o, and I_n are subindexes of faculty compensation, research administrator compensation, other personnel compensation, and nonpersonnel direct research inputs respectively. The subindex of faculty compensation is further broken down into four components:

$$I_f = w_{dh} I_{dh} + w_{fp} I_{fp} + w_{ap} I_{ap} + w_{as} I_{as}, \tag{2}$$

where w_{dh}, w_{fp}, w_{ap}, and w_{as} are expenditure weights for SAES department heads, full professors, associate professors, and assistant professors, and I_{dh}, I_{fp}, I_{ap}, and I_{as} are subindexes of department head, full professor, associate professor, and assistant professor compensation.

The faculty compensation subindexes were based on average annual salaries in SAES (table 1). Average salaries for each of the four faculty categories were divided by their respective average prices in FY 1981/82, the price base period, to produce faculty salary subindexes. I used data on fringe benefits as a percentage of average salary by academic rank in public, doctoral-level institutions to adjust salaries to reflect total compensation. Fringe benefits as a percentage of average academic salaries have steadily increased over time, so omitting the trend in fringe benefits would result in a slight downward bias in the resulting RPI.[2] Data on fringe benefits as a percentage of salary were not available for department heads. Table 2 shows the faculty compensation indexes by academic rank and a weighted index of faculty compensation across all ranks, based on equation 2. The average share of total SAES faculty salary expenditures for FY 1980/81 to 1982/83 served as the weights, as follows: department heads (0.093), professors (0.505), associate professors (0.232), and assistant professors (0.170).

One of the assumptions of a fixed-weighted price index, such as the proposed AG-RPI, is that the "market basket" of items included in the index remains constant over time. Although it was not possible to test this assumption for all items, data were available to test if the faculty weights remained relatively constant. Figure 1 shows the share of total SAES faculty salary expenditures by academic rank for the period covered by the AG-RPI. Faculty shares appear to have been reasonably stable throughout the period. A test for trends in proportions based on Kendall's statistic S was carried out for each faculty rank (*3*). The null hypothesis of no trend was tested against an increasing trend alternative for professors and a decreasing trend alternative for department heads, associate

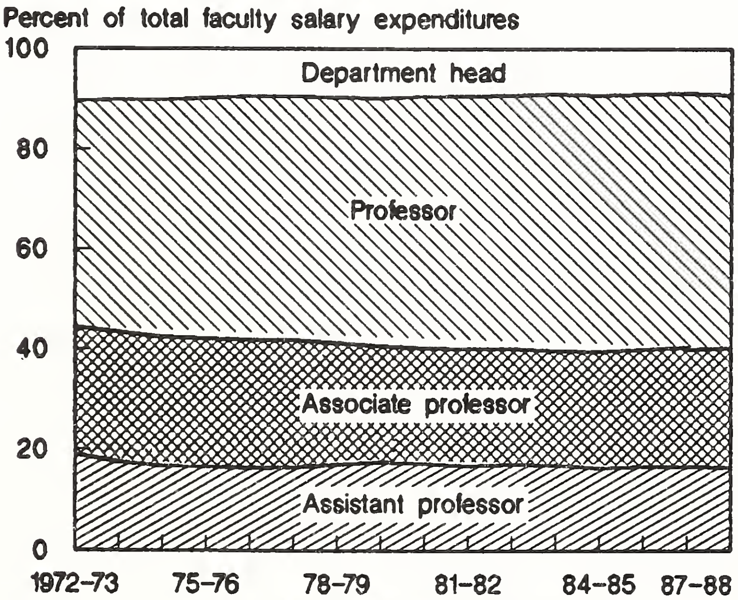
[2]Although the gains in academic fringe benefits shown in table 1 appear to be substantial, they are actually less than the average gains for private-sector employees (2, Jul.-Aug. 1984).

Table 1—Average State Agricultural Experiment Station faculty salaries, average research administrator salary, and fringe benefits as a percentage of average salary, by academic rank

July-June fiscal year	Number of institutions	Average faculty salaries[1]				Average research administrator salary[1]	Fringe benefits as a percentage of average salary[2]		
		Dept. head	Prof.	Assoc. prof.	Asst. prof.		Prof.	Assoc. prof.	Asst. prof.
		Dollars					*Percent*		
1972/73	53	25,490	22,256	17,294	14,798	26,219[3]	11.4	11.8	12.2
1973/74	54	26,682	23,391	18,203	15,502	27,612[3]	12.3	12.9	13.4
1974/75	55	28,244	24,788	19,310	16,324	29,438[3]	12.6	13.2	13.8
1975/76	55	30,293	26,443	20,673	17,352	31,732	13.2	13.7	14.4
1976/77	55	31,621	27,846	21,884	18,342	33,524	13.8	14.3	15.0
1977/78	55	33,656	29,562	23,208	19,489	35,771	14.1	14.8	15.5
1978/79	55	35,449	31,494	24,762	20,792	38,416	15.1	15.9	16.6
1979/80	55	38,600	33,784	26,591	22,175	41,002	16.3	17.0	17.6
1980/81	56	42,214	37,106	28,943	24,306	46,367	17.2	18.0	18.3
1981/82	56	45,935	40,462	31,655	26,474	49,478	18.1	19.1	18.9
1982/83	56	48,737	42,758	33,688	28,133	53,523	18.5	19.5	19.8
1983/84	55	50,358	43,871	34,222	29,075	55,024	19.4[4]	20.7[4]	21.0[4]
1984/85	56	54,272	47,599	36,940	31,352	59,205	20.3	21.8	22.1
1985/86	56	57,534	50,861	39,417	33,430	63,841	20.4	21.8	22.1
1986/87	56	61,036	53,990	41,379	35,309	67,813	20.5	22.0	22.2
1987/88	56	63,653	56,077	43,164	36,845	71,286	20.2	22.0	22.3

[1]Source: USDA, Cooperative State Research Service, salary analysis, various years.
[2]Fringe benefits as a percentage of average salary for faculty in public, doctoral-level institutions. Source: Calculated from AAUP, various years.
[3]Extrapolated as described in the text.
[4]Obtained by linear interpolation between 1982/83 and 1984/85.

Figure 1
Share of total State Agricultural Experiment Station faculty salary expenditures, by academic rank



Source: USDA, Cooperative State Research Service, various years.

professors, and assistant professors. The hypothesis of no trend could not be rejected at a 0.05 level of significance for each academic rank, lending support to the assumption of constant faculty shares over time. USDA Cooperative State Research Service (*23*) data indicate that SAES faculty shares shifted significantly during the 1960's, with professors' shares of salary expenditures steadily increasing while department head and assistant professors' shares declined. This trend appears to have leveled off by the early to mid-1970's.

Research administrator salaries were based on data for FY 1975/76 to 1987/88 that showed average annual salaries of research administrators in "cooperating state institutions" (SAES, forestry schools, 1890 colleges and Tuskegee University, and colleges of veterinary medicine). These data were a weighted average of salaries of directors, associate directors, assistant directors, research directors, administrative technical representatives, deans, associate deans, and assistant deans. The administrator salary series was extrapolated by regressing average research admin-

Table 2—State Agricultural Experiment Station compensation and salary indexes, proxy price indexes, and agricultural research price index (AG-RPI)

July-June fiscal year	Dept. head salary index	Compensation subindexes[1] Prof.	Assoc. prof.	Asst. prof.	Faculty comp-ensation index	Research admin. salary index	Proxy price indexes Other personnel[2]	Nonper-sonnel[3]	AG-RPI
1972/73	55.5	51.9	51.3	52.7	52.2	53.0	50.5	47.4	50.3
1973/74	58.1	55.0	54.5	55.8	55.3	55.8	54.0	51.5	53.7
1974/75	61.5	58.4	58.0	59.0	58.7	59.5	58.2	57.3	58.1
1975/76	65.9	62.6	62.3	63.1	62.9	64.1	64.0	62.2	63.2
1976/77	68.8	66.3	66.3	67.0	66.7	67.8	68.6	66.1	67.3
1977/78	73.3	70.6	70.7	71.5	71.0	72.3	73.3	70.8	71.9
1978/79	77.2	75.9	76.1	77.0	76.3	77.6	78.3	76.7	77.2
1979/80	84.0	82.2	82.5	82.8	82.5	82.9	84.7	84.7	84.0
1980/81	91.9	91.0	90.6	91.3	91.0	93.7	92.2	92.9	92.1
1981/82	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1982/83	106.1	106.0	106.8	107.1	106.4	108.2	108.2	106.0	107.0
1983/84	109.6	109.6	109.6	111.8	110.0	111.2	114.4	111.0	112.0
1984/85	118.1	119.8	119.3	121.6	119.8	119.7	121.1	116.6	119.4
1985/86	125.3	128.1	127.3	129.7	127.9	129.0	126.9	121.2	125.6
1986/87	132.9	136.1	133.9	137.1	135.5	137.1	133.2	125.4	131.7
1987/88	138.6	141.1	139.7	143.2	140.9	144.1	140.1	131.3	137.9

[1]Derived from average SAES faculty salaries and fringe benefits as a percentage of average salary by academic rank (from table 1).
[2]Fixed-weighted price index for: "State and Local Government Compensation of Employees," July-June fiscal year basis. Source: Calculated from quarterly data, U.S. Dept. Commerce (1986) and *Survey of Current Business*, various issues.
[3]Fixed-weighted price index for: "State and Local Government Purchases of Goods and Services," July-June fiscal year basis. Source: Calculated from quarterly data, U.S. Dept. Commerce (1986) and *Survey of Current Business*, various issues.

istrator salary on SAES department head salary and a constant. The resulting coefficients were used to estimate administrator salaries for FY 1972/73 to 1974/75. Data on fringe benefits as a percentage of salary were not available for research administrators. Table 1 shows average administrator salaries, and table 2 shows the administrator salary index.

Because of the lack of data on average unit prices for these research inputs, proxy price indexes were used to represent the inflationary trends in other personnel compensation and nonpersonnel direct research expenditures.[3] Compensation for personnel other than faculty and administrators constitutes a large proportion of SAES research personnel expenditures, and includes professional support, technical support, clerical and other support, and graduate research assistants. The Bureau of Economic Analysis (BEA) index of "State and local government compensation of employees" was chosen as a proxy for other personnel compensation (table 2). Alternative proxies that were examined included two indexes published by the Bureau of Labor Statistics (BLS): a compensation cost index for civilian workers in white-collar occupations, and a compensation cost index for State and local government workers in white-collar occupations (*27*). Both of these alternative proxies closely followed the "State and local government compensation of employees" price trend, but they extend back only to 1981 and therefore could not be used.

The price trend in nonpersonnel direct expenditures is represented by the BEA's price index for "State and local government purchases of goods and services." Alternative proxies for this component of research costs include the wholesale or Producer Price Index (*9, 21*) and the implicit deflator for nonfinancial corporations (*8*). The BEA proxy was selected because it is based on a more relevant subsector of the economy.

The subindexes were then weighted by their respective shares of SAES research expenditures and combined as shown in equation 1. The following SAES expend-

[3]Only one study has attempted to directly measure price change in nonpersonnel research inputs. The Bureau of Labor Statistics (BLS) developed an experimental price index for Army research activities (*26*). The BLS effort involved selecting and pricing a large sample of goods and services representing Army and contractor research expenditures. This approach proved to be feasible but expensive.

iture weights were estimated by Murphy and Kaldor (*15*) for FY 1978/79: faculty (0.309), research administrators (0.019), other personnel (0.387), and nonpersonnel direct expenditures (0.285). Table 2 shows the resulting AG-RPI.

Note that this research price index includes only direct research costs. Indirect costs of research, which cannot be easily allocated to particular projects, include such items as the operation and maintenance of buildings, departmental and research grant administration, depreciation or use charges on facilities and equipment, and libraries. Indirect costs are assumed to have changed proportionately to direct costs. This assumption should tend to bias the AG-RPI downward somewhat, because the percentage of total academic research costs accounted for by indirect costs has increased in recent decades (*11*), and indirect costs have increased more rapidly than direct costs after 1973 (*16*).

Comparison with the GNP Deflator

Is the implicit price deflator for GNP—used in most Government statistics to express research expenditures in constant dollars—an adequate measure of the rate of inflation in SAES research? Figure 2 compares the agricultural research price index constructed in this study with the GNP deflator. The two indexes were remarkably similar throughout the 1970's and early 1980's (the two indexes were forced to converge in the 1981/82 base year), but a widening gap appeared after 1982/83. A test determined if the observed deviation between the AG-RPI and the GNP deflator could be attributed to randomness. Under the null hypothesis that deviations between the two indexes are random over time, we would expect to observe an equal number of positive and negative deviations. With the Chi-square test, the null hypothesis of randomness was rejected at a 0.025 significance level. Thus, evidence indicates nonrandomness in the sequence of deviations between these two price indexes, leading to a reasonable conclusion that the AG-RPI and the GNP deflator are different. By 1987-88, the AG-RPI was about 12.5 percent higher than the GNP deflator, implying that use of the GNP deflator may substantially overestimate the real purchasing power of SAES research.

Figure 2
Comparing the agricultural research price index (AG-RPI) with the implicit price deflator for gross national product (GNP)

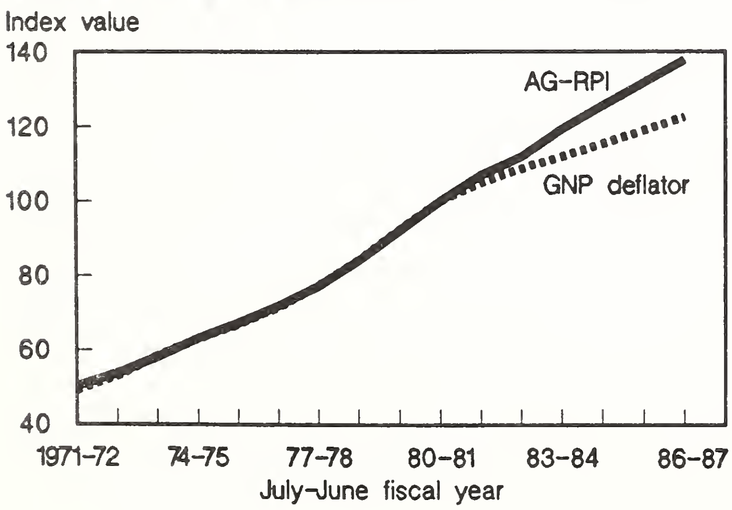


Figure 3 reveals the etiology of the divergence between the AG-RPI and the GNP deflator. Personnel compensation is the major component of the AG-RPI, and these figures present a detailed picture of trends in real compensation over time. Compensation for SAES faculty, faculty in public, doctoral-level universities, and faculty in private, doctoral-level universities failed to keep up with the cost of living throughout the 1970's.[4] By 1980/81, the purchasing power of SAES faculty salary and benefits had dropped to more than 14 percent below the 1972/73 level for assistant professors, 12 percent for associate professors, and 13 percent for professors. Faculty in public and private research universities experienced even greater declines in real compensation during the 1970's and early 1980's. Faculty compensation has grown significantly in real terms in recent years, surpassing 1972/73 purchasing power by 1986/87 in most cases. The 1980's have clearly been a catchup period for U.S. university scientists, making up for ground lost during the 1970's. Figure 3(d) shows that State and local government employees—the proxy used in this study for trends in nonfaculty compensation—have also made gains in real compensation during the 1980's. Trends in real compensation for General Schedule Federal employees and all nondefense Federal employees are also shown for comparison in figure 3(d).

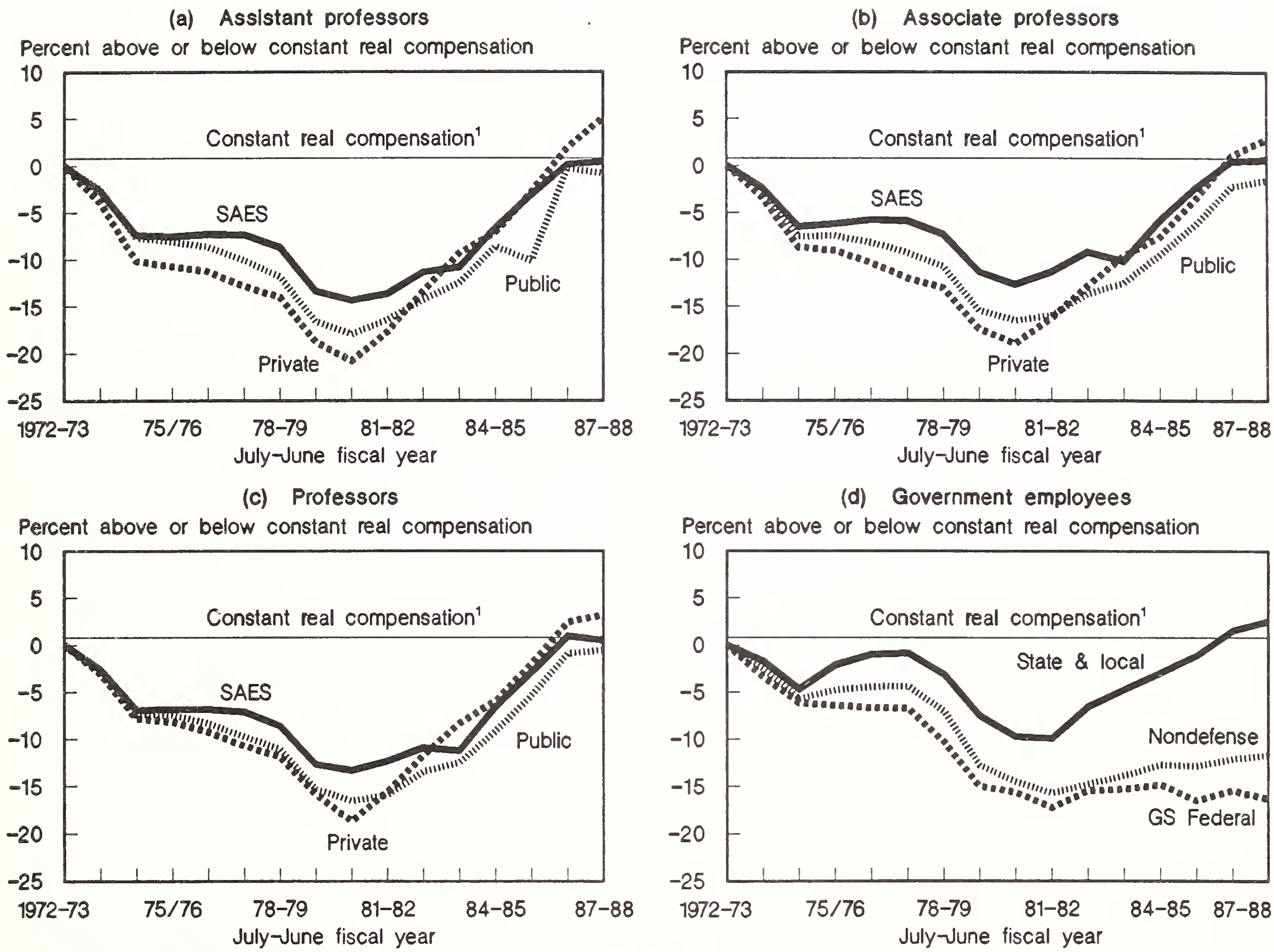
One possible explanation for the real growth in faculty compensation is the effect of collective bargaining in higher education. Faculty collective bargaining agreements spread rapidly during the 1970's, and by late 1987, the faculty at 65 percent of all 4-year public institutions were represented by certified bargaining agents (*6*). Although a few public

[4]The percentage change in real compensation in fig. 3 was calculated as follows:

$$\{[(AC_t/AC_{72\text{-}73}) / (CPI_t/CPI_{72\text{-}73})] - 1\} \times 100,$$

where AC_t is average compensation in fiscal year t, $AC_{72\text{-}73}$ is average compensation in fiscal year 1972/73, and CPI is the Consumer Price Index on a July-June fiscal year basis.

Figure 3
Patterns of change in average real compensation



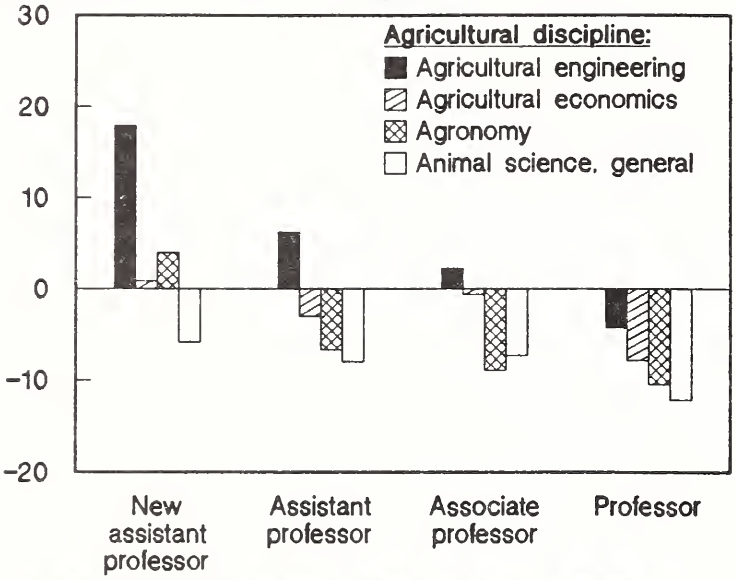
1/ Constant real compensation was measured relative to a July-June fiscal year Consumer Price Index.
Sources and legend labels: SAES: Faculty in State Agricultural Experiment Stations (CSRS, various years); Public: Faculty in public, doctoral-level universities (AAUP, various years); Private: Faculty in private independent, doctoral-level universities (AAUP, various years); State & local: State and local government employees (U.S. Department of Commerce, BEA, and Survey of Current Business, July issues); Nondefense: Nondefense Federal employees (U.S. Department of Commerce, BEA, and Survey of Current Business, July issues); GS Federal: General Service Schedule Federal employees (U.S. Office of Personnel Management, various years).

college and university systems have been entirely unionized, faculty at most of the larger and more prestigious institutions have not been organized. Only about 12 percent of faculty in disciplines related to agriculture are currently covered by collective bargaining agreements, according to a survey that included 49 institutions with these disciplines (*1*). So, a direct effect of collective bargaining on faculty salaries in the SAES is unlikely. But, there may have been an indirect effect. Faculty salaries on non-unionized campuses may have been increased by administrators or legislators either to reduce union activity or to compete more effectively with unionized institutions (*13*).

Another part of the explanation may be that industry and academia are competing for new Ph.D.'s. The index for SAES assistant professor compensation (table 2) has increased slightly more than the indexes for professors and associate professors in recent years, perhaps supporting the hypothesis of competitive entry-level bidding. Figure 4 suggests that competitive bidding may have affected salaries in some, but not all, agricultural disciplines. New assistant professors in agricultural engineering earn on average about 18 percent above the average for new assistant professors in all disciplines in land-grant institutions, with the salary differential decreasing as academic rank increases. Average salaries in other agricultural dis-

Figure 4

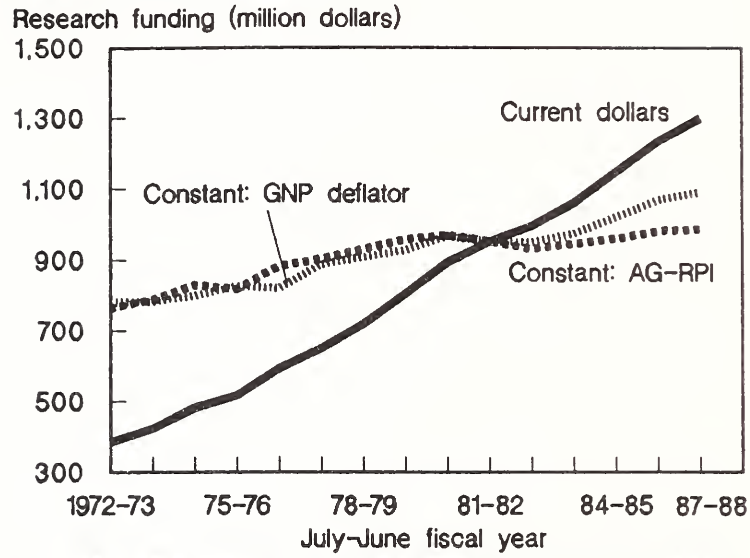
Average salary for four agricultural disciplines relative to average salary for all disciplines in land-grant institutions, by academic rank, FY 1987/88



Source: Office of Institutional Research, Oklahoma State Univ., Stillwater

Figure 5

State Agricltural Experiment Station research funding[1]



1/ In current dollars, constant 1981/82 dollars deflated with the agricultural research price index (Constant: AG-RPI), and constant 1981/82 dollars deflated with the implicit price deflator for gross national product, July-June fiscal year basis (Constant: GNP deflator).

Source for SAES research funding: USDA, Cooperative State Research Service, Inventory of Agricultural Research, various years.

ciplines, such as animal sciences, have consistently lagged behind the average for each academic rank.

Conclusions and Implications

The SAES research price index calculated in this study is subject to the limitations of all fixed-weighted price indexes. Mentioned earlier was the assumption that changes in prices alone, not changes in the "market basket" of included items, are important between the base period and the current period. Another limitation is that like all other price indexes used to deflate research expenditures, the AG-RPI calculated in this study is an index of research *input* prices instead of output prices. Deflating current dollar expenditures with a research input price index requires the assumption of no change in the productivity of research over the relevant time period. An index of agricultural research productivity should ideally be used in conjunction with a research price index. The productivity of the research process is difficult to measure, however, and no satisfactory indicator is available. The relatively short timespan covered by the calculated AG-RPI should preclude serious bias from being introduced due to changes in research productivity.

Given these caveats, two main conclusions can be drawn from this study. First, use of the GNP deflator has very likely resulted in an upward bias in estimates of the magnitude of real SAES research in recent years. Figure 5 shows the trend in SAES research funding in current dollars, constant 1981/82 dollars based on the GNP deflator, and constant 1981/82 dollars based on the AG-RPI. When the GNP deflator is used, real research expenditures appear to be recovering after a slight decline in FY 1981/82 and 1982/83. The estimate based on the AG-RPI has been essentially constant since the early 1980's; real expenditures edged above the 1980/81 level only in 1985/86. In FY 1986/87, the gap between the GNP deflator and the AG-RPI translates into a difference of more than $104 million in the estimate of real SAES research, about 10 percent of the total research budget. This substantial difference points out the inadequacy of the GNP deflator as a measure of inflation in SAES research. The strong real growth in faculty compensation in recent years is not reflected in broad measures of inflation.

Second, nonpersonnel research dollars have been tightly squeezed as faculty compensation has risen in real terms against relatively fixed budgets. The underfunding of expenditures on equipment, facilities, and other nonpersonnel research inputs may be a concern in many institutions. This is likely to be a growing concern in the future. The age distribution of U.S. faculty is such that salaries are expected to continue to rise due to strong demand: "The large surge in faculty hiring in the Sixties has resulted in a tenured U.S. academic faculty of largely the same age . . . which will cause sharp increases in retirement, and consequent demand for new faculty." (*18, p. 4*). Additional upward pressure on faculty salaries will come from demographic trends that indicate a de-

clining production of new scientists in the next decade (*18*).

This study has shown that an alternative price index is needed for SAES research. The prospects for the next decade indicate a continued need for an alternative research deflator for academic research. Without a better research deflator, policymakers who decide on science and technology funding will have an inaccurate view of real resources devoted to SAES research, which could result in a misallocation of resources and underinvestment in research.

References

1. American Association of State Colleges and Universities/College and University Personnel Association. 1987-88 National Faculty Salary Survey by Discipline and Rank in State Colleges and Universities. American Association of State Colleges and Universities and College and University Personnel Association, in conjunction with Appalachian State University, Boone, NC. Washington, DC: College and University Personnel Association, 1988.

2. American Association of University Professors. The annual report on the economic status of the profession, *Academe* (Bulletin of the American Association of University Professors), various years.

3. Armitage, P. "Tests for Linear Trends in Proportions and Frequencies," *Biometrics*. Vol. 11(3), 1955, pp. 375-86.

4. Cline, Phillip L. "Sources of Productivity Change in United States Agriculture." Ph.D. thesis, Oklahoma State University, Stillwater, 1975.

5. Davis, J.S. "Stability of the Research Production Coefficient for U.S. Agriculture." Ph.D. thesis, University of Minnesota, St. Paul, 1979.

6. Douglas, Joel M. (with Beth Genya Cohen). *Directory of Faculty Contracts and Bargaining Agents in Institutions of Higher Education*. The National Center for the Study of Collective Bargaining in Higher Education and the Professions, Baruch College, City University of New York. Vol. 14, Jan. 1988.

7. Eddleman, B.R. *Change in Prices of Agricultural Research Inputs*. Mississippi Agriculture and Forestry Experiment Station, Mississippi State University. IR-6 Information Report No. 2, 1980.

8. Griliches, Zvi (ed.) "Comment," *R&D, Patents, and Productivity*. National Bureau of Economic Research Conference Report. Chicago: Univ. of Chicago Press, 1984, pp. 148-49.

9. Huffman, Wallace E., and Robert E. Evenson. *The Development of U.S. Agricultural Research and Education: An Economic Perspective*. Part I, Staff Paper No. 168. Dept. Economics, Iowa State University, Ames, Apr. 30, 1987 (revised December 1988).

10. Jaffe, Sidney A. *A Price Index for Deflation of Academic R&D Expenditures*. NSF 72-310. Washington, DC: National Science Foundation, 1972.

11. Kennedy, Donald. "Government Policies and the Cost of Doing Research," *Science*. Vol. 227(4686), 1985, pp. 480-84.

12. Mansfield, E., A. Romeo, and L. Switzer. "R&D Price Indexes and Real R&D Expenditures in the United States," *Research Policy*. Vol. 12(2), 1983, pp. 105-12.

13. Marshall, Joan L. "The Effects of Collective Bargaining on Faculty Salaries in Higher Education," *Journal of Higher Education*. Vol. 50(3), 1979, pp. 310-22.

14. Milius, Susan. "Collective Bargaining Seen as Boon to Science Salaries," *The Scientist*. Vol. 2(14), 1988, p. 19.

15. Murphy, Joseph W., and Donald R. Kaldor. "The Changing Cost of Performing Agricultural Research: An Index Number Approach," *Evaluation of Agricultural Research*, George Norton and others (eds.). Misc. Publication 8-1981, Minnesota Agricultural Experiment Station, University of Minnesota, St. Paul, 1981, pp. 187-95.

16. National Association of College and University Business Officers. *University Price Index Calculation System*. National Science Foundation. Contract No. NSF C-SRS77-26298, Feb. 1979.

17. National Association of State Universities and Land-Grant Colleges. 1987-88 Faculty Salary Survey of Institutions Belonging to National Association of State Universities and Land-Grant Colleges. Office of Institutional Research, Oklahoma State University, Stillwater, 1988.

18. National Science Foundation. *Future Costs of Research: The Next Decade for Academe*. PRA Report 87-1, 1987.

19. Pardey, Phillip G., Barbara Craig, and Michelle L. Hallaway. "U.S. Agricultural Research Deflators: 1890-1985," *Research Policy.* Vol. 18(5), 1989, pp. 289-96.

20. Schankerman, Mark A. "Essays on the Economics of Technical Change: The Determinants, Rate of Return, and Productivity Impact of Research and Development." Ph.D. thesis, Harvard University, Cambridge, MA, 1979.

21. Sonka, S.T., and D.I. Padberg. *Estimation of an Academic Research and Development Price Index.* Illinois Agricultural Economics Staff Paper No. 79 E-100. Dept. of Agricultural Economics, University of Illinois, Urbana-Champaign, 1979.

22. U.S. Congress, Office of Technology Assessment. *Impact of Inflation on the Federal R and D Investment.* Staff paper prepared by the National R&D Policies and Priorities Program, June 1980.

23. U.S. Department of Agriculture, Cooperative State Research Service. *Salary Analysis for State Agricultural Experiment Stations, Forestry Schools, Colleges of 1890 and Tuskegee University, and Schools of Veterinary Medicine.* Unnumbered bulletin, various years.

24. U.S. Department of Agriculture, Cooperative State Research Service. *Inventory of Agricultural Research,* various years.

25. U.S. Department of Commerce, Bureau of Economic Analysis. *The National Income and Product Accounts of the United States, 1929-1982,* 1986.

26. U.S. Department of Labor, Bureau of Labor Statistics. *Experimental Input Price Indexes for Research and Development, Fiscal Years 1961-65.* Report NSF 70-7, Contract No. G 13542, Nov. 1970.

27. U.S. Department of Labor, Bureau of Labor Statistics. *Current Wage Developments.* Vol. 40, No. 3, 1988.

28. U.S. General Accounting Office. *Science Indicators: Improvements Needed in Design, Construction, and Interpretation.* Report by the Comptroller General of the United States, PAD-79-35, Sept. 25, 1979.

29. U.S. Office of Personnel Management. *General Schedule Salary Tables.* OPM Doc. 124-48-6, various years.

A Framework for Examining Technical Change

Mary K. Knudson and Bruce A. Larson

Abstract. *Technical change is dynamic, recursive, and endogenous to the economic system. However, empirical studies usually treat technology as exogenous, defining technical change in terms of its end result: changes in some production possibilities set. An endogenous view of technical change is necessary to understand, anticipate, and perhaps alter the development and use of new technologies and their associated problems. This article outlines a conceptual framework in which technical change is endogenous. The framework accounts for the dynamic and recursive interactions between research and development activities, the adoption and diffusion of new innovations, and the regulatory and institutional environment. As an example, the development of glyphosate-tolerant crops is discussed to show how the framework can be used to identify, organize, and understand the important variables and relationships for a specific case of technical change.*

Keywords. *Technical change, research and development, adoption, diffusion, regulation, glyphosate tolerance.*

The impact of technical change on economic growth has been well known since Adam Smith's *Wealth of Nations* (*32*).[1] More recently, Solow (*34*) attributed 87.5 percent of the longrun growth in U.S. output to technical change. Although technical change is an important source of economic growth, the use of technology is tied to many existing agricultural and resource problems. New technologies will likely help solve these problems while simultaneously creating the next generation of problems. For example, the use of chemicals and conventional tillage in agriculture is partially responsible for surface- and ground-water contamination. But new technologies, such as genetically engineered plants with nitrogen-fixing abilities or tolerance to pests, may reduce the need for chemical applications.

While technical change is a dynamic and recursive process that is endogenous to the economic system, empirical studies usually treat technology as exogenous, and define technical change in terms of its end result—changes in some production possibilities set. An endogenous view of technical change is necessary to understand, anticipate, and perhaps alter the development and use of new technologies and their associated new problems.

Economic literature contains many studies addressing technical change as an endogenous component of the economic system. Griliches (*10*), Metcalfe and Gibbons (*24*), Hayami and Ruttan (*12*), and Johnson (*14*) have analyzed particular aspects of technical change and, in various ways, have discussed the need for an endogenous view of technical change. Excellent reviews of various aspects of the subject can be found in (*4*, *7*, *15*, *28*, and *35*).

At this time, however, the enormous amount of research in this area has not been integrated into a systematic, cohesive whole. The objectives of this article are to: (1) present a conceptual framework for examining technical change as an endogenous process that integrates the many individual issues found in the literature, and (2) demonstrate the framework's usefulness in explaining the development of a biotechnology product, namely glyphosate-tolerant crops. Glyphosate, sold under such names as Round-Up, a trademark of Monsanto, is a broad spectrum, nonspecific herbicide that kills annual sedges, grasses, and broadleafed plants. However, via biotechnology methods, glyphosate can now be applied to certain crops (tomatoes, tobacco, cotton, soybeans, canola) that it would otherwise kill.

A Conceptual Framework

This section integrates the key relationships identified in the literature on technical change into a unified conceptual framework by first defining the concepts of technology and technical change. We then define major components of technical change, after which the links between each component are discussed in detail.

Technology is generally the application of accumulated knowledge in society, and technical change is the application of new knowledge. Economists tend to use the term, technology, to describe a relatively specific and discrete way of producing something. We follow Mundlack and define a technique according to a

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[1]Italicized numbers in parentheses cite sources listed in the References section at the end of this article.

conventional input requirement set and a technology as the convex hull of the technique input requirement sets, where there is little cost beyond factor prices of switching among techniques within a technology (*25*).[2] Using this definition, we associate two technologies with two sets of techniques, and technical change is a switch to or creation of another technology. Figure 1 shows our conceptual outline.[3]

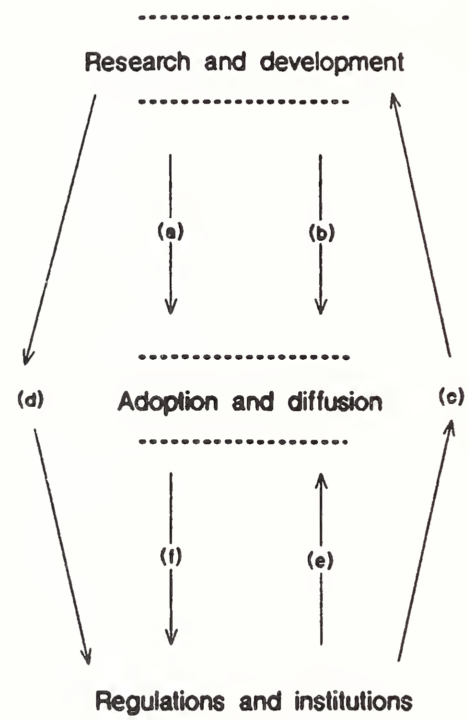
The Three Components

The research and development (R&D) component involves the creation and application of knowledge. This component provides the set of technologies from which firms and consumers choose. R&D is usually separated into three stages: basic research extends the scientific frontiers of knowledge; product development evolves from applied research; and commercial development focuses on market testing and release.

The allocation of R&D funds is a classic portfolio selection problem and, therefore, uncertainty and costs strongly determine the allocation of resources to R&D projects. During basic or applied research, technical uncertainty exists about the success of the project. Even if a project is technically successful, uncertainty surrounds the possible economic benefits. The source of funds for a research program provides an additional source of uncertainty. Projects may become impossible to complete within a budget constraint, and research programs that span years or decades can be canceled. Costs begin to mushroom as research progresses toward commercial development. For example, in plant breeding, the commercial testing of a new variety is twice as expensive as the total cost of all its preceding basic and applied research (*8*).

The adoption and diffusion (A&D) component pertains to firms and consumers who decide to buy new innovations. The study of technology adoption focuses on if, when, and why a firm decides to use an alternative or new technology, or a consumer decides to buy a new product (*7, 19*). Several factors affect the decision to adopt an innovation, most notably the performance and relative cost of the innovation, the level of risk aversion, the existence of complementary inputs, and the skill needed to use the innovation. The study of technology diffusion focuses on the spread of technology over time and can be measured at various degrees of aggregation, such as the farm, county, State, regional, or national levels (*10, 29*).

Figure 1
The process of technical change



The regulations and institutions (R&I) component defines the economic, social, legal, and political environment for the R&D and A&D components. The institutional setting can both impede and facilitate the process of technical change. Harl emphasizes that "one of the significant problems faced by the Third World is the lack of an institutional framework for the development and diffusion of new technologies. . . " (*11*, p. 112). While the significance of the institutional setting for technical change is often emphasized in a developing country context (*7, 14*), its role in western and centrally planned countries is equally strong. For example, LeBlanc and Hrubovcak attribute about 20 percent of aggregate investment in U.S. agriculture to tax regulations over the period 1956 to 1978 (*18*). The U.S. Cooperative Extension Service, created through public policy, brings together farmers, scientists, and government agencies for the transfer and exchange of information on new technology and needs for new technologies.

We now turn to the links between the three components of technical change. Figure 1's arrows indicate the direction of influence. The three components of technical change are tied together in a dynamic and

[2]More specifically, with inputs x, the jth technique can be written as a production function $F_j(x)$, and a technology T is a set of techniques $T = [F_1(x),\ldots F_J(x)$. The input requirement set for T is the convex hull of the input requirement sets for the individual techniques (*25*).

[3]Technology continuously evolves over time, and developments in one area can be expected to have spill-over into other areas. For the purpose of this article, we focus on technical change in a single area.

recursive fashion. Due to the recursive nature of these relationships, however, defining a "starting point" for the process of technical change can be difficult. Depending on the case, certain relationships are obviously more important, and the following discussion is designed to identify the relevant links for a particular study.

The Links Between Components[4]

a. The effect of R&D on the A&D component has been studied extensively as the supply-push view of technical change. The supply-push view considers technical change to be driven by "autonomous advances in scientific and technical knowledge" (*35*, p. 8). Economic forces have no initial influence on the creation of new knowledge. Thus, the R&D component provides the set of opportunities among which firms and consumers choose.

While it is hazardous to define an advance in scientific knowledge as "autonomous," initial developments in biotechnology seem to offer an example of supply-push. In 1973, tools to splice and move DNA pieces between different organisms were discovered (*26*). These tools eventually gave scientists the ability to transfer genes between different species which otherwise would not have been possible. As a result, opportunities opened up for understanding and manipulating the physiology and biochemical pathways of organisms.

b. The demand-pull view of technical change emphasizes how the demands of firms and consumers induce and direct R&D activities which are driven by attempts to take advantage of profitable opportunities. The adoption and diffusion of technologies provide new signals to the R&D component about the current and potential market success of an innovation. Market success or failure in turn provides incentives to the R&D component to continue or halt further production, marketing, and development. After market introduction, innovations are often further developed and improved, increasing consumer attractability, decreasing average costs, and pushing out of the market other competing firms and products (*1*, *23*, *24*).

Even though general developments in biotechnology gave scientists the ability to create glyphosate-tolerant crops, the perceived opportunity to develop a commercial product directed research toward developing these crops. Glyphosate is the largest selling herbicide, accounting for $400 million in annual sales (*17*). Glyphosate-tolerant crops meant the market could expand from the few million acres treated to around 150 million acres (*17*).

Public perception influences the adoption and further development of new technologies.[5] Public perceptions, which include safety and environmental concerns like toxic residues in food and social concerns like the protection of rural communities, have been an obstacle for biotechnology R&D. For example, some feel that produce from glyphosate-tolerant plants may contain toxic residue. Whether or not residues actually exist in the produce, such a perception could alter the adoption and diffusion of glyphosate-tolerant varieties. The importance of public perceptions has spawned education and media programs as an integral component of most biotechnology research programs.

c. Regulations and institutions clearly affect the ability and incentives to conduct R&D. Regulations are enforced at the Federal, State, and local levels and directly limit or increase the cost to the firm of conducting certain R&D activities. The R&I component influences the size and allocation of public research dollars, property rights in new technologies, liability for environmental and human health problems, and market prices.

Agricultural biotechnology regulation provides an excellent example of how the R&I component changes the incentives to conduct R&D. The Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the U.S. Department of Agriculture (USDA) are the main agencies that oversee agricultural R&D.[6] EPA activities may intersect with FDA activities because chemicals are one form of food contaminant, while all of these agencies have more specialized roles in biotechnology. Other Federal agencies in the regulatory process include the National Institutes of Health (NIH) and the Occupational Safety and Health Administration (OSHA).

The indirect costs involved in R&D are substantial. For example, firms and research institutions spend time and money to complete tests and apply for

[4]Sub-headings a-f relate to the same letters in fig. 1.

[5]Smith and others (*33*) showed how lack of consumer confidence (a perception) after a food safety problem significantly affected product demand. (Restoring consumer confidence is difficult.)

[6]The EPA regulates microbial products, including pesticides, subject to the Federal Insecticide, Fungicide, and Rodenticide Act and the Toxic Substances Control Act (*26*). The FDA regulates the use of food additives, drugs for humans and animals, and food contaminants, and has established different safety levels for each of these areas (*20*). The USDA tests for plant pests, including organisms and products altered, by using genetic engineering under the Plant Pest Act (*26*).

permits to meet regulatory requirements, a process that may not be directly productive from the firm's point of view and can substantially increase the cost of an R&D program. Biotechnology managers speculate that they will spend $10-40 million per product to meet regulatory guidelines for new drugs, pesticides, or food additives (*21*, p. 97). Only research institutions or firms that can afford these directly unproductive costs as well as the direct research costs are able to continue to operate. Thus, the R&I component can influence the general structure of the R&D industry, including the size and number of firms and entry costs.

Regulations that are well defined, clearly established, not redundant, and not in conflict with other regulations reduce uncertainty and facilitate long-term planning. Regulations that do not meet these conditions delay progress, unnecessarily increase the costs of R&D, and may stop some R&D completely. According to the Office of Technology Assessment (OTA), "regulatory uncertainty, for example, affects decisions by companies on whether to spend $1-$2 million on greenhouses only because of concern over future field test versus greenhouse work. . . " (*27*, p. 211). An added incentive to invest in greenhouse space exists if permits for field testing are difficult and costly to obtain.

The cost of time and money of meeting regulatory requirements for glyphosate research has been significant. Private companies have been the principal developers, and the EPA is currently the principal regulator of glyphosate-tolerant crop varieties. Before the first field test, industry had to apply for testing privileges with the EPA and now must repeat a similar process before testing glyphosate-tolerant crops at a commercial level. Until recently, the large amount of paperwork was a disincentive to R&D. However, informational requirements in the regulatory process have now become more streamlined (*30*). Such work is not necessarily redundant if new information is acquired during the sequential application process.

Like many areas of research, more than one agency will be involved in regulating glyphosate-tolerant crops through to commercial development. The FDA may move into this area to test for residue left by a marker gene that accompanies the transferred gene.[7,8] Scientists and administrators are worried that FDA requirements may repeat those of the EPA, or may even require returning to a smaller scale of testing. To provide a clear and consistent regulatory environment, the EPA, FDA, and USDA have conducted joint reviews of research projects such as a joint regulatory review recently completed for Crops Genetic International.

d. The R&D component has a direct and recursive effect on the regulatory and institutional setting in which it is conducted. The information and technologies from R&D activities are often associated with new social/moral issues, such as the ability to create transgenic animals, split atoms, clone cells, or mine oceans. In response, the R&I component continually evolves to accommodate new opportunities and problems. Biotechnology prompted much debate about ethical issues involved in the patenting of new life forms before such patents were initially granted.

Progress in biotechnology, and the uncertainty associated with potentially unwanted side effects, forced Federal and State governments to evaluate, alter, and create regulation for biotechnology R&D. Since the government had no prior experience with these technologies, and the uncertainty about their environmental impacts were substantial, regulatory policies were not as coherent as some researchers would have preferred. Research scientists demanded and are still demanding a clearer, less costly set of R&D regulations. Through such forums as the Transgenic Plant Conference in 1988 and the Federal and State Biotechnology Conference in 1989, government and scientific communities are discussing improvements in regulations.

e. The R&I component is naturally tied to the adoption and diffusion of technologies. Regulations and institutions define constraints and objective functions that structure the decisionmaking environment and exchange possibilities of firms and consumers. Regulations directly ban or limit certain activities, indirectly affecting others' activities through input prices, output prices, borrowing and lending constraints, and other costs. Beyond market incentives, firm and consumer objective functions (profits, utility) are also driven by the social, ethnic, environmental, and cultural background.

The effect of government programs, and their relation to technology adoption, is clear in the tobacco industry. For example, in March 1989, tobacco growers indicated that they planned to increase plantings by 13 percent over 1988 levels in direct response to an 11-percent increase in the effective quota for flue-cured tobacco, about a 20-percent increase for burley, and

[7]In presentations during the Transgenic Plant Conference, Annapolis, MD, September 7-9, 1988, Stephen Rogers from Monsanto suggested that the FDA may consider testing for possible changes in foods that are produced via genetic engineering.

[8]Glyphosate tolerance is achieved through transferring a mutated gene, which is tolerant of glyphosate, from a wild petunia to a tomato plant, with a marker gene, which, if it appears, indicates transformation has occurred.

larger allotments for other types of tobacco (*37*). Because tobacco quotas effectively limit acreage planted, the adoption and diffusion of glyphosate-tolerant tobacco varieties can be expected to depend on the prevailing government programs at the time of market release.

f. The adoption and diffusion of technologies create new environmental, economic, and social conditions that, over time, change the R&I component. The adoption and diffusion of new technologies change the structure of agriculture, including location of production, farm size, and numbers of operators. This well-known phenomenon is related to the technology treadmill and the evolution toward a larger scale agriculture (*3*).

The recent emergence of biotechnology and its products have caused farmer and consumer groups (the potential adopters) to demand new regulation, both to accelerate the transfer of new technologies to the market and to restrict certain activities. Segments of both groups believe that current Federal regulations may result in some unsafe field testing (*22*). These groups feel that the regulatory flaws include confusing definitions of biotechnology, incomplete coverage of research activities, and weak environmental mandates.[9]

Consumer groups in California stopped the first field tests of Frost Ban, the biotechnology product that would decrease frost damage (*17*). Due to local worries that the bovine growth hormone (bGH) will be biased toward large farms and accelerate the decline in the family farm, research on bGH may no longer be continued at some land grant universities (*5*). Concern has also been raised about potential side effects of consuming milk produced using bGH technology (*5*), although the FDA has approved the sale of milk for human consumption from FDA-approved research herds treated with bGH (*6*).

Implementing the Conceptual Framework

The conceptual framework is useful if it helps to organize and explain specific cases of technical change. An appropriate test of the framework would be to compare the relationships in figure 1 with a group of specific case studies of new technologies (including those that never reached the market). Such an empirical study must wait for research. Meantime, this section briefly reviews the development of glyphosate tolerance in tomatoes to summarize the main points of the framework. Because glyphosate-tolerant tomatoes are not yet commercially available, we also use the framework to hypothesize about the future importance of certain relationships.

Research and development in glyphosate began as a supply-push phenomenon (R&D → A&D), after the first transfer of genes in plants using biotechnology. Plant biotechnology initially used crops most amenable to gene transfer techniques and whose genomes (chromosome set) were already well mapped. Tomatoes, potatoes, and tobacco fell into this category. Thus, general developments in gene transfer techniques, when combined with earlier research on the genome structure of tomatoes, created the necessary technical preconditions for the development of glyphosate-tolerant tomatoes.

However, the potential market for new seeds from biotechnology attracted R&D investments toward the area of herbicide tolerance (A&D → R&D). For example, after a survey of 24 firms conducting biotechnology research, Hayenga reported that they typically chose projects with expected markets of more than $10 million per year (*13*). The seed market in general, and glyphosate in particular, meets this requirement. The market for glyphosate, the world's largest selling herbicide, could significantly expand with the emergence of glyphosate-tolerant crop varieties.

Because of slow growth in the agricultural chemicals market, chemical companies became interested in seed biotechnology (*16*). Through the development of seed varieties tolerant to herbicides, like glyphosate, opportunities arose to create and expand chemical markets.

Monsanto, a chemical company, and Calgene, a biotechnology company, are the two developers of glyphosate-tolerant tomatoes. Field tests of glyphosate-tolerant tomatoes began in 1987 when Monsanto planted 22 different lines of tomatoes in Illinois. These lines tolerated commercial rates of glyphosate application, which is 0.5 to 1 pound per acre (*9, 31*). Monsanto conducted field tests in Illinois and California in 1988. Calgene held field tests in California during 1988 and 1989 (*36*). Based on current information, glyphosate-tolerant tomatoes are expected to be commercially available by 1993 or 1994 (*31*).

Farmers' perceptions of performance, relative costs, and associated risks, as well as consumer acceptance of the fruit, will affect the adoption and diffusion of

[9]See (*22*) for a detailed discussion.

glyphosate-tolerant tomato seeds. Potential benefits are lower overall application rates of herbicides, lower herbicide costs, and less crop damage. Glyphosate-tolerant plants, however, could carry over as weeds, or could cross with weedy relatives and introduce tolerance into the environment (*2*). While crop management programs can solve such problems, the associated cost diminishes the benefits of adopting glyphosate-tolerant varieties. But, weedy relatives of tomatoes do not grow in the United States, so tomatoes will not likely cross with other plants.

We do not know how the adoption of glyphosate-tolerant seeds will affect the use of other herbicides. For example, glyphosate could displace other herbicides and require fewer applications. Some argue, however, that the benefits from glyphosate may encourage liberal applications of both glyphosate and other herbicides (*13, 17*). Until glyphosate-tolerant tomatoes are commercially available, the debate will continue about the possible environmental impacts of the adoption and diffusion of it.

Developments in water-quality regulation probably will greatly affect the outcome of this debate (R&I → A&D). For example, water-quality policy may inhibit liberal use of glyphosate through taxing, restricting, or banning certain inputs and practices that pollute ground water. The 1990 farm bill, in which water-quality policy is expected to be a major issue, may provide signals about the future direction of environmental policy in the farm sector.

Residue from the marker gene for the transferred glyphosate tolerance system could build up in the fruit. So, consumer acceptance of the tomatoes from glyphosate-tolerant plants, whether based on perceptions or scientific information, will affect the market price, and, therefore, the revenue side of the farmer's adoption decision.[10]

Due to environmental safety and human health concerns raised by consumer, scientific, and environmental groups, Federal regulation has evolved to cover biotechnology activities (A&D → R&I, and R&D → R&I). Because glyphosate is a herbicide, the EPA has jurisdiction over the field testing of glyphosate-tolerant crops. Monsanto and Calgene have had to apply for experimental permits from EPA for each field location (R&I → R&D).

[10]Consumers have been skeptical of the safety of biotechnology products. For example, in an OTA survey, 52 percent believed that biotechnology could be a serious threat to health and the environment (*26*).

The effect of regulatory costs on the incentives to invest in R&D is debated and remains unclear. Because the material Monsanto provided for the 1987 and 1988 field tests were almost identical, the regulatory process could create unnecessary costs and act as a disincentive to R&D (R&I → R&D).[11] The current permit process though is designed to access the potential risks of general areas of research as quickly as possible. Certain subjects will be identified as relatively safe and will be exempt from permit requirements or have a simplified process. Costs of regulation can be expected to decline over time, potential accidents and lawsuits may be avoided, and consumer acceptance of products from biotechnology may increase.

The conceptual framework outlined in this paper suggests that the six relationships in figure 1 will influence the direction of technical change. Glyphosate tolerance in tomatoes clearly shows that each of these relationships is currently affecting the development of one product from biotechnology. The framework also identifies specific issues that must be addressed, such as the relationship between future environmental policy and the incentives to adopt and use new technologies, before the market and social impacts of a new technology can be assessed.

Conclusions

The process of technical change is endogenous to the dynamic system within society. The framework is simple yet complete enough to detect the main factors that drive technical change. The emphasis on the three components of technical change allows the various theories of technical change to be drawn together, more easily related to one another, broadened, and enriched. By focusing on the process of technical change, we can understand and direct the path of change toward socially acceptable outcomes.

References

1. Arthur, W.B. *Competing Technologies: An Overview.* Center of Economic Policy Research Paper No. 98. Stanford University, Stanford, CA, 1987.

2. Boyce Thompson Institute. *Regulatory Considerations: Genetically-Engineered Plants.* Center for Science Information. San Francisco, 1987.

3. Cochrane, W.W. *Farm Prices: Myth and Reality.* Minneapolis: University of Minnesota Press, 1958.

[11]Hayenga also reports that the cost of gathering data for a field-test application is $250,000 or more (*13*).

4. Dosi, G. "Sources, Procedures, and Microeconomic Effects of Innovation," *Journal of Economic Literature.* Vol. XXVI, 1988, pp. 1,120-71.

5. Ehart, O. Speech from *Federal-State Regulation of Biotechnology—Plants/Microorganisms.* Research Triangle, North Carolina. June 25-28, 1989.

6. Fallert, R., T. McGuckin, C. Betts, and G. Bruner. *bST and the Dairy Industry: A Summary Analysis.* AIB-535. U.S. Dept. Agr., Econ. Res. Serv., Oct. 1987.

7. Feder, G., R.E. Just, and D. Zilberman. "Adoption of Agricultural Innovations in Developing Countries: A Survey," *Economic Development and Cultural Change.* 1985, pp. 255-98.

8. Geadelmann, J. Personal communication with Holden Seeds, 1986.

9. *Genetic Technology News.* Vol. 8, No. 6, June 1988.

10. Griliches, Z. "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica.* Vol. 25, 1957, pp. 501-22.

11. Harl, N. "A Discussion," *Agriculture and Rural Areas Approaching the Twenty-first Century.* (R.J. Hildreth and others, eds.), Ames: Iowa State University Press, 1988, pp. 109-14.

12. Hayami, H., and V.W. Ruttan. *Agricultural Development: An International Perspective.* Baltimore: The Johns Hopkins University Press, 1985 (2nd printing).

13. Hayenga, M.L. "Biotechnology in the Food and Agricultural Sector: Issues and Implications for the 1990s." University of California Agricultural Issues Center, Davis. Paper No. 88-5. 1988.

14. Johnson, G.L. "Technological Innovations with Implications for Agricultural Economics," *Agriculture and Rural Areas Approaching the Twenty-first Century.* (R.J. Hildreth and others, eds.), Ames: Iowa State University Press, 1988, pp. 82-108.

15. Kennedy, C., and A. Thirlwall. "Technical Progress: A Survey," *Economic Journal.* Vol. 82, 1972, pp. 11-72.

16. Kidd, G.H. "Heading for the Future: Seed and Plant Biotechnology." Paper from AgBioTech Conference, Arlington, VA. March 1989.

17. Kloppenburg, J., Jr. *First the Seed: The Political Economy of Plant Biotechnology 1492 - 2000.* Cambridge: Cambridge University Press, 1988.

18. Le Blanc, M., and J. Hrubovcak. " The Effects of Tax Policy on Aggregate Agricultural Investment," *American Journal of Agricultural Economics.* Vol. 68, 1986, pp. 767-77.

19. Lindner, R.K. "Adoption as a Decision Theoretic Process." Ph.D. thesis, Department of Agricultural and Applied Economics, University of Minnesota, St. Paul, 1981.

20. Marraro, C.H. "Regulating Food Additives and Contaminants," *Quantitative Risk Assessment in Regulation.* L.B. Lave (ed.). Washington, DC: The Brookings Institution, 1982, pp. 213-31.

21. Meeusen, R.L. "Insect-Resistant Higher Plants: A Case Study of Regulation Under the Coordinated Framework," *Regulatory Considerations: Genetically-Engineered Plants.* San Francisco: Center for Science Information, 1987.

22. Mellon, M. "Regulation," *Biotechnology and the Environment.* National Biotechnology Policy Center, National Wildlife Federation, Washington, DC, 1988, pp. 37-49.

23. Metcalfe, J.S. "Technological Innovation and the Competitive Process," *Greek Economic Review.* Vol. 6, 1984, pp. 287-316.

24. Metcalfe, J.S., and M. Gibbons. "Industrial Policy and the Evolution of Technology," *Technological Innovation and Production Structure: The Position of Italy Conference.* Milan, 1983.

25. Mundlack, Y. "Endogenous Technology and the Measurement of Productivity," *Agricultural Productivity, Measurement and Explanation.* (S.M. Capalbo and J.M. Antle, eds.). Resources for the Future, Washington, DC, pp. 316-31.

26. Office of Technology Assessment. *New Developments in Biotechnology. Field-Testing Engineered Organisms: Genetic and Ecological Issues.* 1988.

27. Office of Technology Assessment. *New Developments in Biotechnology: U.S. Investment in Biotechnology.* 1988.

28. Peterson, W., and Y. Hayami. "Technical Change in Agriculture," *A Survey of Agricultural Economics Literature.* Vol. II (G.C. Judge and others,

eds.), Minneapolis: University of Minnesota Press, 1977, pp. 497-540.

29. Rogers, E.M. *Diffusion of Innovations.* New York: Free Press, 1983.

30. Rogers, S.G. Personal communication with Monsanto Co., St. Louis, 1988.

31. Rogers, S.G. *Field Testing and Commercialization of Transgenic Crops.* Paper given at the Transgenic Plant Conference, Annapolis, MD, Sept. 1988.

32. Smith, A. *An Inquiry into the Nature and Causes of the Wealth of Nations.* Chicago: University of Chicago Press, 1976. (First published in 1776.)

33. Smith, M.E., E. Van Ravenswaay, and S.R. Thompson. "Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii," *American Journal of Agricultural Economics.* Vol. 70, 1985, pp. 513-20.

34. Solow, R.M. "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics.* Vol. 70, 1956, pp. 65-94.

35. Thirtle, C.G., and V.W. Ruttan. *The Role of Demand and Supply in the Generation and Diffusion of Technical Change.* Bulletin No. 86-5, Economic Development Center, University of Minnesota, Minneapolis, 1986.

36. U.S. Department of Agriculture. *Permits Issued for Release into the Environment Under 7 CRR 340.* June 15, 1989.

37. U.S. Department of Agriculture, Economic Research Service. *Tobacco Situation and Outlook Report.* TS-206. Apr. 1989.

Getting the Word Out at ERS

Editor's note: The enormous advance in the technology of information management has influenced the research community and how it goes about its jobs. If the technical changes in data handling are to be matched by organizational and institutional changes, regular reassessment of both needs and capabilities must be made. Problems of access, disclosure, respondent relations, and quality evaluation represent legitimate concerns of the research community. Economics is no exception. As an illustration of both concerns and proposed solutions, the Journal asked Ed Reinsel to report on the Economic Research Service's policy on dissemination of statistics, and Jim Horsfield to report on the Agency's Data Products Program.

The ERS Data Products Program

James Horsfield

Section 1121 of the Food Security Act of 1985 is particularly important to researchers and analysts interested in agriculture and rural affairs. It authorizes the Secretary of Agriculture to furnish electronic materials prepared in the Department, to charge reasonable fees for them, and to use the fees collected to offset the costs of providing the materials. Before enactment of this provision, electronic data dissemination in the Department was governed by the User Fee Statute,[1] which permits the collection of user fees established by regulation but specifically disallows agency use of the fees to offset costs. Thus, the 1985 Act reversed the Department's incentives to prepare and distribute electronic materials: it permits agencies to recover costs and removes the requirement for a regulatory process to establish fees.

The Economic Research Service was one of the first USDA agencies to begin an electronic data dissemination program based on Section 1121. ERS Administrator John Lee established the Standard Data Products Program in May 1986. This program provides copies of ERS data bases and data files for sale to the public. These products are data bases with a substantial ERS value-added component and are of a one-time nature without periodic updates. Accordingly, the program does not provide a subscription service for monthly or quarterly copies of current data. Products on personal computer diskettes and conventional magnetic tapes are available but each product is offered in only one medium. User fees for fiscal year 1990 are $130 for tape products and $25 and up for diskette products, depending on the number of the disks.

Eighteen data products were offered in the first year of the program, including data bases on such diverse topics as farm income, dry beans, rural fire protection, and fertilizer use. The current catalog lists 71 titles representing all ERS programs.[2] Many of these products give users the electronic equivalent of published data such as the ERS situation and outlook yearbooks. Other products supplement and extend published data or provide access to unpublished data not otherwise available to non-ERS users.

The agency first expected use primarily by researchers and agribusiness analysts. Data product users, however, are not so easily classified. Orders come from a wide variety of users from around the world: farmers, consumers, interest groups, State and local government agencies, and businesses. These orders are processed by the ERS-NASS order desk,[3] which offers a toll-free number for telephone orders and a variety of payment methods including several national charge cards.

ERS extended the services of the data products program to the American Agricultural Economics Association and the Rural Sociological Society in 1988 as a cooperative data sharing program. This program accepts data products from members of the two groups and advertises them in a special section of the *ERS Electronic Products Catalog.* Because user fees cover all program costs, the program furnishes a timely and cost-effective mechanism for sharing data.

Policy on Dissemination of Statistical Information

Edward I. Reinsel

ERS provides economic and social science information and analysis for improving the performance of the agricultural economy and rural America. In support of that mission the ERS policy is to: (1) maximize

[1]31 U.S. Code 9701.

[2]Copies of the *ERS Electronic Products Catalog* are available free from the ERS-NASS order desk at 1-800-999-6779.

[3]Operated jointly with the National Agricultural Statistics Service (NASS).

availability of data and information and encourage its broader use, (2) minimize restrictions on release of information, (3) strengthen the quality of statistical data, and (4) insure against any breach of confidentiality.

The policy applies to all summary and micro data under ERS control. It applies to all data derived from Federal surveys or administrative records as well as data obtained from State agencies, universities, foreign governments, international organizations, and other domestic or foreign sources. Under the policy, data purchased in summarized form are immediately available to all ERS users. After 6 months, with approval of the agency providing the summaries, the data will be available for more general distribution. Data received by ERS on individual farms that cannot be released because of confidentiality are first summarized, then made available to ERS staff and published for more general use.

Certain restricted or classified information is not disseminated, such as information bearing on national security and data that could reveal proprietary information about an individual respondent, farm, or firm. All written or oral statements to survey respondents, or conditions listed on administrative forms from which data may be taken or summarized are honored.

ERS-published statistics must have clearly defined and documented definitions available to users. As new definitions or changes are adopted, ERS explains them. ERS furnishes background information on survey and other data collection procedures, fully describes the content of data and tabulations, and evaluates the reliability and usefulness of the data. Such explanations, descriptions, and evaluations may be published separately or along with the data. The objective is to maximize the usefulness of ERS data and to minimize the likelihood that they will be misunderstood or misused.

Estimates are not published from sample surveys unless sufficient reports are received to provide statistically valid results which are clearly free of disclosure of information about individual respondents. This means that at least three observations must be available, although more observations may be necessary in some cases. ERS supplies as much information as possible on nonsampling errors, response rates, and bias. ERS publication of estimates based on probability surveys is accompanied by statistical measures of variation. When data series are built up from several sources, characteristics of the underlying data, including any measures of statistical precision, are described.

ERS publishes information about revisions to strengthen confidence in published estimates and data series. ERS identifies procedural changes, improved or more recent data, and any correction of errors that result in significant revisions (those that have the potential of changing the way a given situation is viewed or which could result in substantial changes in dollar values or in human impacts) to make the procedures as clear as possible.

Standard electronic data products are prepared and released with statistical bulletins, situation and outlook yearbooks, and other publications that include considerable data in tabular form. Published tables may not include all of the data available in standard data products. ERS does not reproduce data which are more directly available from other organizations on tapes, diskettes, or similar forms. Requests for such data are referred to the originating organization.

ERS publications typically follow statistical classifications and definitions adopted by the Office of Management and Budget and USDA. To the extent feasible, ERS uses the Standard Industrial Classification (SIC) in publishing establishment data by industry type. When publishing business size statistics by revenue or assets, ERS uses the dollar size categories adopted by OMB to the extent that data are available. Exceptions to this general policy are made only when the exception will provide analytical insights that might otherwise be precluded by adherence to established classifications and definitions.

Statistical Series Handbook

In cooperation with other USDA agencies, ERS is completing a 12-volume handbook on the Department's statistical series (Agriculture Handbook No. 671, Major Statistical Series of the U.S. Department of Agriculture).

The handbook is designed to help government, university, private sector, and other users become better acquainted with concepts and data underlying the Department's statistics. The handbook should benefit new users of USDA statistics as well as readers already familiar with many of the data series. Data users should find the handbook valuable in improving their knowledge of what the various data series measure and how appropriate they may be for specific uses.

Individual volumes in the handbook are:

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2. Agricultural Production and Efficiency
3. Farm Income
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5. Consumption and Utilization of Agricultural Products
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7. Crop and Livestock Estimates
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Empirical Analysis as the Application of Theory

Applied Production Analysis: A Dual Approach. *By Robert G. Chambers. Cambridge: Cambridge University Press, 1988, 331 pages, $18.95 (paper), $49.50 (hardcover).*

Reviewed by Bruce A. Larson

Hypothesizing that empirical analysis is a rigorous form of theoretical investigation using real-world data, this book provides a concise and focused treatment of the theory of the firm under certainty using the dual approach. Written from the point of view that empirical analysis (and theoretical analysis) is a prisoner of its underlying assumptions, this book stresses the links and possible tradeoffs between theoretical assumptions and empirical necessity. While most of the material in the book is available in previous articles and books, graduate students and economists not schooled in the dual approach—the intended audience—will for the most part appreciate the book's simple style (basic calculus and linear algebra). The author offers a synthesis of more technical literature and a discussion of some fundamentals for applied economics, such as separability, aggregation, technical change, and flexible functional forms. Applied economists will probably find the book a useful reference in day-to-day research.

The "economics" underlying the dual approach utilized by Professor Chambers is simple and focused: the firm has a technology that uses variable and fixed inputs to produce outputs; the firm chooses variable inputs to minimize costs of producing a given level of outputs; and, when appropriate, the firm chooses outputs to maximize profits (revenues minus costs). Thus, the logic of the book's structure is clear. The basic properties and characteristics of production functions are explained and developed first. The cost function follows from the cost-minimization hypothesis, given a production function. And, the profit function follows from the profit-maximization hypothesis, given a cost function, which, in turn, presumes a production function.

The core chapters on the production, cost, and profit functions are developed in a straightforward manner. The topic-oriented chapters, which pull together and simplify a large amount of rather technical material, provide the extra level of understanding and perspective needed for empirical research. For example, while the duality approach presupposes firm-level optimizing behavior, empirical studies often rely on data aggregated across firms as well as across inputs and commodities, a point that may be underemphasized in graduate microeconomic theory courses. Thus, I suspect the sections on aggregation across firms and separability, which allow aggregation across commodities and prices, will be most informative. However, the discussion of the uses of separability (p. 118), which introduced the notion of index numbers, surprisingly did not introduce or at least mention some frequently used indexes, such as the divisia index. The divisia index was not introduced until the discussion of measures of technical change (p. 230).

Using a parametric approach for empirical research means that nothing can be done without choosing a functional form. Here, Professor Chambers provides a reasonable perspective on the choice of a functional form and what one can expect from flexible functional forms: "choosing a functional form is more a craft than a science" (p. 159), "the main attraction of flexible forms does not lie in their ability to closely approximate arbitrary technologies" (p. 179), and "even if flexible forms are not restrictive, their ability to approximate arbitrary technologies is limited" (p. 177). The concept is clear: empirical (and theoretical) research necessarily involves assumptions, and it is imperative to understand how these assumptions influence and condition results.

While the author acknowledges that the chapter on technical change is primarily a catalog of certain types of technical change, the energy was well spent on the discussion. The emphasis on disembodied technical change is appropriate given the objective of the book and the seemingly unlimited ability of time trends to appear in empirical studies to represent technical change. The discussion of various terms and definitions that surround the measurement of technical change (Hicks neutrality, Harrod neutrality, factor augmenting, embodied, disembodied) methodically develops the effects of technical change in production on costs and profits.

The book carves a useful niche in the set of economic texts and supplementary reading packets. It lands

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between more elementary (non-Ph.D.level) texts and those more rigorously developed, although the intended audience may wonder why certain proofs were "left to the reader" or considered to be "beyond the scope" of the book. The book generally accomplishes what it intends to do, but there is still a gap to be filled by a text that would assist the applied researcher struggling with a dynamic and uncertain world. Perhaps Chambers will turn his attention to these issues in future editions.

Demand Response to Price—Multiple Views from the Water's Edge

Elasticities in International Agricultural Trade. Edited by Colin A. Carter and Walter H. Gardiner. Boulder, CO: Westview Press, 1988, 316 pages, $38.50.

Reviewed by Leroy L. Blakeslee

Samuelson registered a negative view of "... certain dimensionless expressions called elasticity coefficients" by noting that, "On the whole, it appears their importance is not very great except possibly as mental exercises for beginning students."[1] As a generalization, this may be an overstatement. I agree with its assessments of price elasticities of demand for agricultural exports or imports. Certainly this book conveys the impression that these elasticities are likely to be unstable, and that a clear elaboration of the complex processes that determine price response must be the first order of business.

The nine chapters of this volume cite recent experience in modeling agricultural trade flows, particularly in determining how border prices affect demand for imports and exports. Several of the authors review related recent works. The book provides a reasonable status report on current theoretical and empirical efforts on trade. In one sense, the results reported are quite discouraging. Wide variation exists in empirical results, and few clear principles emerge concerning the best modeling approaches to be taken to even fairly narrowly defined problems.

Following the good introductory chapter by Gardiner and Carter, an appropriate place to start reading this collection is at Goddard's chapter. She lays out more clearly then elsewhere an important dichotomy that exists in approaches to trade modeling as currently practiced. One approach assumes that similar goods produced in different countries are perfect substitutes. The other assumes them to be less than perfect substitutes. The latter approach, as explained by Goddard, is in the spirit of Armington, though not identical to it. Her development of the elasticities of export demand with respect to border price under the two cases is especially instructive, both to her own results concerning trade in beef as well as to the rest of the book. Abbott's discussion of trade flow rigidity suggests that goods from different sources may be regarded as imperfect substitutes because of long-standing historical, cultural, and political interactions as well as differences in physical attributes. He argues that the Armington approach has merit as a representation of all these conditions.

Virtually all authors of this volume cite the pervasive tendency of governments to intervene in agricultural trade as a major factor making trade modeling difficult. Indigenous agricultural price and income policies that don't directly involve intervention at the border, but do influence trade indirectly, are also mentioned as complicating factors. All authors except Adelman and Robinson, Blandford, and Goddard seem to view the introduction of an elasticity of indigenous market price with respect to border price at values of less than 1.0 as the principal means available for capturing the effects of this intervention and the effect it has on isolating individual country markets from world markets. The authors who did not take this stand took no position at all.

The basic algebra is laid out most simply by Dutton and Grennes (at least for the case where goods from all countries are treated as perfect substitutes). Others, especially Abbott, provide elaboration on this theme and reviews of studies which have used this approach. The chapter by Tyers and Anderson describes a model with extensive use of this construct to capture effects of both protectionist and stabilization policies. However, their description is cryptic, and many readers will find it difficult to fathom the rationale for the precise forms that are used.

While there are many difficulties in developing agricultural trade models that are useful for prediction, I believe government intervention in pursuit of varied and often unclear goals presents the greatest challenges. Intervention often results in little price transmission and reduced effects of border prices on trade as claimed by these authors, but simple price linkage equations or transmission elasticities are frail beasts for carrying so heavy a load. Bolling's brief review of price policies from 1966 through the mid-1980's in nine Latin American countries provides a sobering reminder of the complexity of these policies and of the frequent, major changes that have occurred. Bolling estimates price and exchange rate transmission elasticities based on a simple specification in the spirit of Bredahl, Myers, and Collins[2] and others.

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[1]Paul A. Samuelson, *Foundations of Economic Analysis* (Cambridge: Harvard University Press, 1947), p. 125.

[2]M.E. Bredahl, W. Meyers, and K.J. Collins, "The Elasticity of Foreign Demand for U.S. Agricultural Products: The Importance of the Price Transmission Elasticity," *American Journal of Agricultural Economics*, 61 (1979): 58-62.

She concludes that "... there is no reason to expect these elasticities to be the same in the 80's as they were in the 60's and 70's. They depend too much on the vagaries of politics in each country" (p. 179). The 1986 study by Roe, Shane, and Vo,[3] cited by Carter and Gardiner and by Dutton and Grennes, provides at least a beginning attempt at a more promising approach to introducing the effects of government intervention. A report on their work would have been an interesting addition to the collection of papers in this volume.

Thursby and Thursby recommend that in light of the uncertainties surrounding correct specification in econometric models of agricultural trade, it is appropriate to subject such models to a variety of specification tests. Their ideas are well founded and worth reading. They and others also argue that greater attention should be given to consistency between models used in empirical work and the underlying behavioral models. It is hard to argue with this. However, the fact than an important subset of the behavior being modeled is that of government officials involved in market intervention, and that we know little about the goals they are pursuing, suggests that this will be difficult. The examples presented by Thursby and Thursby imply that behavioral models of government intervention are beyond what they had in mind.

Dutton and Grennes give an interesting and readable treatment of the role of exchange rates in agricultural trade models. Especially instructive is their elaboration on the role of nontradeables in determining export response to prices and exchange rates. Their empirical results are mixed, but their statistical work is pursued in a setting that is perhaps too simplified to produce definitive results.

Books containing a collection of independently developed papers are often faulted for lack of integration, continuity, synthesis, and critical contrast, and this one is no exception. Its final chapter, "Discussion and Concluding Comments" by Myers, Schmitz, Thompson, and McCalla, modestly summarizes the collection.

What can be said for the book? There are no major breakthroughs. I don't believe the book contains papers of the kind that will be on many required reading lists for graduate courses dealing with agricultural trade 10 years from now. Yet, agricultural trade modeling issues are high on the agenda of the discipline at this time. For the reader with a background in theory-based applied econometrics, this book can serve as a good one-stop report on current thinking concerning alternative approaches. I recommend it for this purpose. Parts of the book can supply useful supplementary readings for a graduate course on agricultural trade issues as long as a background is developed in class or from other readings. Worthwhile reading, yes, but I suggest that readers use the library's copy and conserve their book-buying budgets for more definitive works.

The papers include: (1) "Issues Associated with Elasticities in International Agricultural Trade" by Walter H. Gardiner and Colin A. Carter; (2) "Elasticities in International Trade: Theoretical and Methodological Issues" by Jerry G. Thursby and Marie C. Thursby; (3) "Estimating U.S. Agricultural Export Demand Elasticities: Econometric and Economic Issues" by Philip C. Abbott; (4) "The Role of Exchange Rates in Trade Models" by John Dutton and Thomas Grennes; (5) "Macroeconomic Shocks, Foreign Trade, and Structural Adjustment: A General Equilibrium Analysis of the U.S. Economy, 1982-1986" by Irma Adelman and Sherman Robinson; (6) "Price and Exchange Rate Transmission Revisited: The Latin-America Case" by Christine Bolling; (7) "Market Share Models and the Elasticity of Demand for U.S. Agricultural Exports" by David Blandford; (8) "Export Demand Elasticity in the World Market for Beef" by Ellen W. Goddard; (9) "Imperfect Price Transmission and Implied Trade Elasticities in a Multi-Commodity World" by Rod Tyers and Kym Anderson; and (10) "Discussion and Concluding Comments" by William H. Meyers, Andrew Schmitz, Robert Thompson, and Alex F. McCalla.

[3]T. Roe, M. Shane, and D.H. Vo, *Price Responsiveness of World Grain Markets*, TB-1720, U.S. Department of Agriculture, Economic Research Service, June 1986.

Policy Intervention and Unstable Markets

Agricultural Stability and Farm Programs: Concepts, Evidence, and Implications. *Edited by Daniel A. Sumner. Boulder, CO: Westview Press, 1988, 177 pages, $23.50.*

Reviewed by Margot Anderson

Books like this one on the pervasive instability in agricultural markets and the efficacy of government intervention are always timely, even more so when budgets are under review and agricultural policies are being reconsidered within the GATT. This worthwhile collection of six papers, the output of a symposium supported by The Farm Foundation, the North Carolina Agricultural Research Service, and Resources For the Future, addresses sources of instability, their economic effects, and the rationale and effectiveness of agricultural policy.

The collection contains general essays on the causes and effects of instability and case studies of specific policies and markets. Its likely audience is broad, including graduate students in agricultural policy, practicing economists, and policy analysts. Some of the topics addressed in this collection have been previously published in journals or presented at professional meetings. The advantage of the book format is that it provides space for more detailed discussion of each topic. The required level of economic rigor needed for a full appreciation of the essays varies from an elementary background in supply and demand analysis to more advanced training in economic theory. Each essay is followed by a commentary from a symposium participant.

The first essay (Meyers and Oehmke) and the last (Rausser) provide a background for understanding the causes of instability and its potentially adverse effects on economic efficiency. Meyers and Oehmke focus their essay on instability and risk as courses of market failure. While the existence of market failure can provide the rationale for government intervention, the authors argue that the efficiency gains from policy may be quite small. Three types of market failure associated with instability are discussed: 1) disequilibrium (due to sticky prices from price rigidities and long-term fixed contracts), 2) incomplete forward markets, and 3) incomplete contingency markets. The difficult task of devising and implementing corrective policies rests on an adequate body of empirical estimates of the efficiency losses from these market failures. To date, the existing estimates indicate that the efficiency losses are small. More important, the authors implicitly stress the need for further empirical analysis on efficiency losses due to market failures.

Rausser examines the causes of instability by grouping them into three categories: internal, external, and government instability. The discussion on internal instability, such as instability caused by environmental shocks, inelastic demand, asset fixity, and incomplete risk markets, covers familiar ground. Rausser's coverage of external disturbance arising from macroeconomic and trade factors acknowledges more recent explanations of instability. Rausser presents a concise review of both price overshooting and trade effects of volatile macroeconomic policies.

Both essays present discussions on instability created by government policies. Rausser has long been associated with examining how intervention policies designed to correct for internal and external instability can themselves be destabilizing. This type of nonmarket failure, which is frequently overlooked in agricultural economics literature, occurs because policies may induce outcomes that can be less efficient than in an unregulated and imperfect market. The political process that creates agricultural policy can be influenced by nonefficiency goals, such as maximizing agricultural budgets or appeasing powerful special interest groups. The resultant effect can induce resource allocations that are no more efficient than nonintervention resource allocation.

Fackler's essay compares government policies with market-based institutions designed for stabilization. For example, options and futures markets are similar to price supports, but the costs and benefits are significantly different and must by considered by advocates of a more market-oriented agricultural sector. Not discussed in Fackler's essay, but worth attention, are market-oriented stabilization schemes and institutions commonly used in other agricultural subsectors like poultry and fruit and vegetable markets. These markets also exhibit instability, although for different reasons, but there is less government intervention.

Two case studies are also presented in the collection. Martin examines stabilization schemes for the feed grain markets; Sumner examines the tobacco pro-

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gram. Both essays discuss the evolution of policies and present estimates of the efficacy of stabilization policies.

While collections of papers are not intended to be exhaustive, some additional topics might have been considered. An essay or discussion of the connection between instability and uncertainty would have been beneficial. These concepts are not synonymous, and as pointed out in Sumner's introductory remarks, the rationale for some types of stabilization policy can be predicated on instability alone. But, unanticipated changes in costs and revenues may be more important for other stabilization schemes. The book also needed a brief discussion of volatility in other industries. How volatile are prices and incomes in other industries? Consideration of policy goals, other than economic efficiency, could have been included, too. These goals might include the effects of stabilization policies implemented to achieve equity or smooth adjustment or to correct for instability caused by macroeconomic policies.

A small point on measures of instability: coefficients of variation, such as those reported by Martin, may be inappropriate measures of instability. This would be the case if the variables are not normally distributed which is unlikely given the extremely small sample sizes and existence of outliers, particularly during the 1970-79 period. Robust estimates of scale and location, however, exist as do hypothesis tests that could compare measures of variability across time for normal data.

The papers include: (1) "Instability and Risk as Rationales for Farm Programs" by Robert J. Meyers and James F. Oehmke; (2) "Storage, Stability, and Farm Programs" by Brian D. Wright; (3) "An Analysis of Alternative Market and Governmental Risk Transference Mechanism" by Paul Fackler; (4) "Stability and Farm Programs: A Case Study of Feed Grain Markets" by Marshall A. Martin; (5) "Stability and the Tobacco Program" by Daniel A. Sumner; (6) "Stability Issues and Policy Analysis" by Gordon A. Rausser.

Farm Policy—In Plain English

Basic Mechanisms of U.S. Farm Policy, by USDA's Economic Research Service, demystifies and clarifies farm legislation and the programs spawned by it. It describes in plain English the key concepts of how U.S. farm policy works and takes you step-by-step through the major programs.

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SOME BASIC MECHANISMS OF U.S. FARM POLICY

Target Price	Projected Deficiency
Loan (Nonrecourse loan) Rate	Advance Deficiency
Deficiency Payment	Base Acres & Program Yield
Original Deficiency	0-92 & 50-92
Reduced (Findley) Loan Rate	Commodity Certificate
Emergency Compensation	Posted County Price (PCP)
Acreage Reduction Program (ARP)	PIK and Roll
Paid Diversion	Export Enhancement
Base Acres	Farmer-Owned Reserve (FOR)
Program Yield	Corn (& Wheat) Catalog
Program Production	Reserve Rollover
Basic Commodities	Conservation Reserve Program
Acreage Conservation Reserve	Disaster Payment
Conservation Use	Marketing Loan
Payment Limitation	

Part one of this report concentrates on the left side of this list, and Part two covers the seven mechanisms at the top right.

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